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ACOUSTIC AND ELASTIC PROPERTIES OF WOOD FOR VIOLIN SOUND POST

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Abstract: The sound post is a very important element in the acoustics of musical instruments with strings and bows. This paper presents the experimental investigations regarding the elastic and acoustic properties of the wood used to obtain the sound post. The speed of propagation of sound waves in wood and then the determination of the elastic properties in the longitudinal direction was measured on a number of 12 sound posts made from new and old resonance wood. It was found that the elastic and acoustic properties depend on the degree of aging of the wood. Thus, the longitudinal propagation speed is about 4% higher in samples of freshly processed wood compared to those of aged wood; the longitudinal modulus of elasticity is about 19% lower for aged wood samples.
Key words: resonance wood, soundpost, violin, elastic properties, wave velocity in wood.

1. INTRODUCTION

The violin is a wooden ensemble that includes about 40 elements - some with an acoustic role, others with an aesthetic or functional role. A very important element in transmitting vibrations from the front plate to the back plate is the sound post. The sound post is positioned inside the violin, being inserted after the completion of the violin, through the acoustic hole f, next to the inner notch of the f. The sound post fixation ensures the tension of the front and rear plates so as to obtain a clear, strong, bright sound of the violin (Figure 1). Therefore, the geometric shape, the position inside the violin body and the material from which the bow is made, are important factors that both violinists and violinists take into account [1–5]. Sound post is a cylindrical rod about 55 - 65 mm long and 5 - 6 mm in diameter, which has the role of adjusting the tension of the resonant plates, and its position can be adjusted. The fixing of the sound post is obtained as a result of the forced insertion between the top and the back plate. he main role of the sound pole is in fact to introduce asymmetry into the design of the instrument body, thus disturbing the symmetry of the vibration modes and maintaining a balance between structural and air vibrations in the acoustic cavity (violin body). The transfer of the vibration energy of the strings is done from the vibrating rope to the cord (gag) to which the strings are fixed. It propagates the vibration to the sound board (top plate) which begins to vibrate, entraining the air inside the body. Due to the longitudinal and transverse vibrations of the plates, as well as the vibration of the air in the cavity, the oscillating movement is transmitted to the sides and the back plate which in turn introduces into the system an oscillating movement of the air inside the body. Thus the air pressure in the box changes periodically, acting as a Helmholtz type resonator. Taking into account the contour conditions, the sound waves are reflected and radiated by the walls of the box in all directions, producing the composition of sound waves under a rich spectrum of harmonics [6–10]. Estimations of the elastic and acoustic properties were made by methods based on ultrasound [4, 10–16]. [3] reported for resonance spruce with density of $0.400\ g/cm^3$, $0.400\ g/cm^3$, the following longitudinal velocities $c_L = 5600\ m/s$; $c_T = 1600\ m/s$; $c_R = 2000\ m/s$, and for shear velocity $c_{LT} = 1425\ m/s$; $c_{RT} = 298\ m/s$; $c_{LR} = 1374\ m/s$ and for common spruce: $\rho = 0.485\ g/cm^3$, the following longitudinal velocities $c_L = 5353\ m/s$; $c_T = 1146 m/s$; $c_R = 1580\ m/s$, and for shear velocity $c_{LT} = 1230\ m/s$; $c_{RT} = 477\ m/s$; $c_{LR} = 1322\ m/s$.

2. MATERIALS AND METHOD

2.1 Materials

In this study, two sets of wood samples were analysed resonant spruce, depending on the age of the wood: the samples coded from 1.1 - 1.6 are made of wood with a maximum age of the semi-finished products of 3 years, and those coded 2.1 - 2.6 are made of wood about 10 years old. The geometric characteristics of the samples are presented in Table 1.

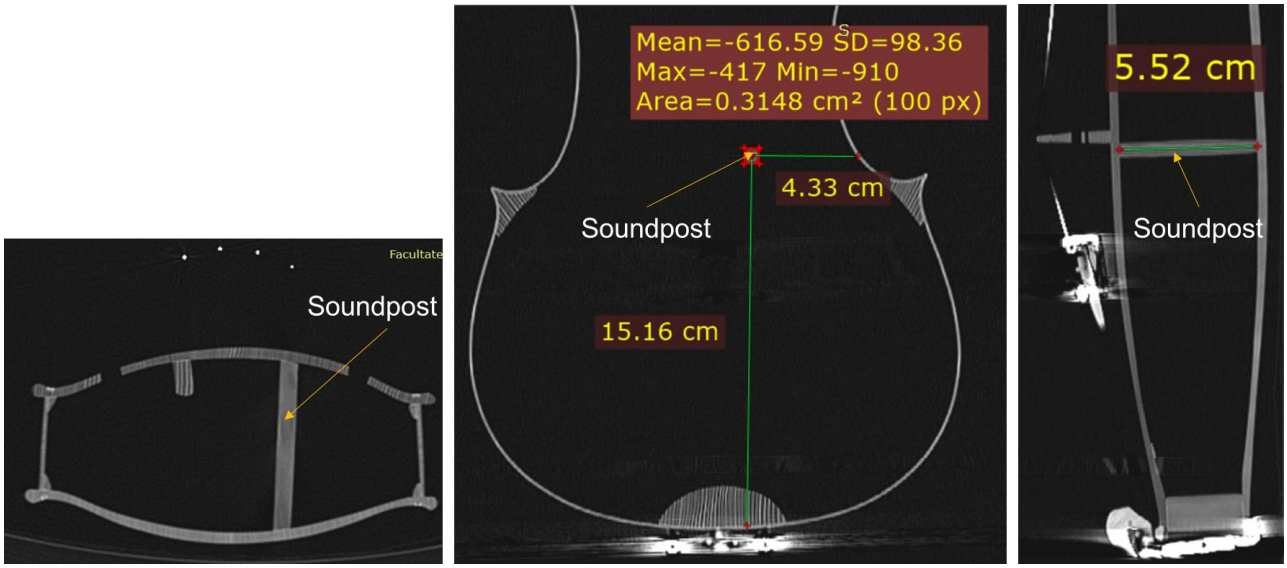

Fig. 1. Positioning the sound post inside the violin (computer tomography images)

Table 1. The geometrical and physical features of samples

Sample code	Length (mm)	Diameter (mm)	Mass (g)	Volume (mm^3)	Density (kg/m^3)	The age of the semi-finished products (years)
1.1	62.59	5.8	0.8435	1652.839	510	3
1.2	64.40	6.2	1.0857	1943.296	559	3
1.3	63.83	6.06	0.9602	1840.093	522	3
1.4	61.25	6.08	0.9582	1777.391	539	3
1.5	64.40	5.9	0.95	1759.785	540	3
1.6	62.94	5.8	0.8682	1662.082	522	3
2.1	59.72	5.85	0.6551	1604.358	408	10
2.2	59.00	5.68	0.616	1494.233	412	10
2.3	60.23	5.85	0.6759	1618.059	418	10
2.4	60.23	5.73	0.7871	1552.358	507	10
2.5	59.82	5.84	0.8325	1601.555	520	10
2.6	60.00	5.92	0.8465	1650.685	513	10

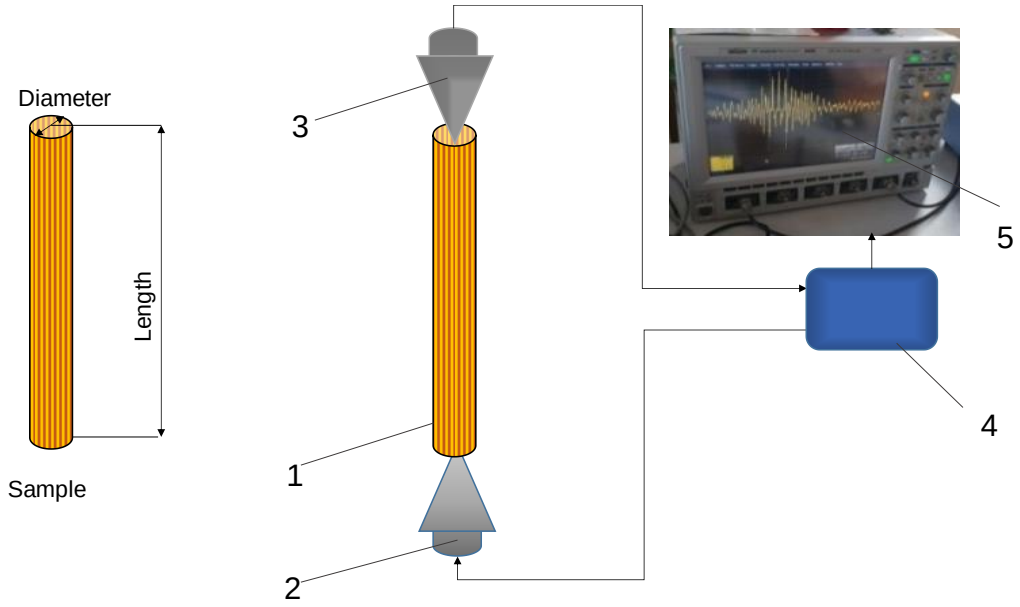

Fig.2. Experimental set-up: 1 – sample; 2 – transmitter; 3 – receiver; 4 – generator; 5 – oscilloscope

2.2 Methods

The determination of the elastic and acoustic properties of the sound post was performed based on the ultrasound method. The ultrasound (US) nondestructive evaluation consists in the applying a physical elastic waves to the sample tested and analyzing the interaction between materials samples and field. To increase the reliability and assurance quality of measurement, the ultrafine force presses the US sensors with constant value. The two buffer rods of US sensors used at the emission and reception are both identical, being made of the 7075-T6 aluminum-magnesium alloy, with the density 2.7x103 kg/m3, the Young modulus 7x1010N/m2, the Poisson coefficient 0.34 and a point curvature radius of 2mm. The US sensors are connected to a 5073PR Pulse Receiver – Panametrics equipment. The visualization of the signal and the measurement of the time of propagation were made with Le Croy Wave Runner 64Xi digital oscilloscope, with sampling frequency of 10G S/s. The samples were marked to identify the position of US transducer center in the measurement points corresponding to two opposite faces (Figure 2).

3. RESULTS AND DISCUSSIONS

The aging of spruce wood leads to changes in its microstructure which is reflected in changes in elastic and acoustic characteristics, as evidenced by the comparative analysis of sound posts of new wood and aged wood (Table 2). In general, all physical, elastic and acoustic sizes tend to decrease in the case of aged wood (Figure 3). Thus, the density of wood older than 10 years decreased by about 12% compared to that of wood older than 3 years (Figure 3, a). This is due to changes in the structure of the cell walls of the wood. The speed of sound propagation in wood decreases by about 4 % (Figure 3, b). It can be considered that by aging the wood, the wood is dried, the water bound from the wood in the form of OH groups stabilizing. Thus, the volume of air in the cell lumen increases, leading to a decrease in the speed of sound propagation. The biggest change in elastic properties is obtained for the modulus of elasticity which decreases by 20% in 10-year-old wood (Figure 3, c).

a)

b)

c)

Fig. 3. Comparison between acoustic and elastic properties of new and old sound posts

Table 2. The values of elastic and acoustic properties

Types of samples	Ultrasound velocity (m/s)				Young's Modulus (GPa)			
	Average	STDV	min	max	Average	STDV	min	max
Set 1	5352.774	81.79185	5235.772	5457.627	15.24517	0.6462295	14.358	16.079
Set 2	5143.981	1.783734	5000	5217.391	12.284	1.7837343	10.306	14.065

4. CONCLUSION

This paper aimed to determine the acoustic and elastic characteristics of resonant spruce wood used as violin sound post. Two types of sound posts were tested in terms of material age. The test method was based on measuring the ultrasonic propagation speed in wood, in the longitudinal direction.

•due to the aging of the wood, its density decreases by about 12% compared to the new wood. The natural drying of wood leads to the removal of water from cell membranes and cell voids.

•The speed of sound propagation in the sound post of new wood is about 4% higher than that of aged wood, this is due to the bound water content of the new wood.

•The modulus of longitudinal elasticity is about 12% lower in aged wood compared to new.

In conclusion, the sound velocity in wood the longitudinal direction and the longitudinal elasticity modulus are the most important properties that differentiate the quality classes of resonant spruce. Aged wood has significantly lower sound propagation speeds in wood and modulus of elasticity than in new wood.

In future studies, the influence of the age of the sound post wood on the vibration modes of the violins will be analysed.

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