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THE SURFACE ENERGY OF COATING LAYERS USED FOR VIOLINS VARNISHING

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Abstract: Numerous studies on new and historical violins have highlighted the importance of coatings for the acoustics of the musical instrument. The purpose of this paper is to present the results regarding the surface energy of resonant wood, spruce and maple in two states: lacquered and unvarnished. The method is based on static contact angle measurements of sessile drops. The obtained results highlight large differences in surface energy depending on the wood section (radial versus longitudinal), surface (lacquered versus unvarnished), wood species. Thus, although the surfaces are polar for both unpainted and lacquered samples, it can be seen that there is a tendency to increase the contact angle after applying the surface treatment (applying the varnish). In the case of spruce wood cut in the longitudinal direction, the contact angle increases by about 31% in the case of the lacquered surface. For maple wood, the increase is 10%. For radially cut spruce wood samples, it is observed that the contact angle is higher than 90°, the surface having a hydrophobic character, a characteristic that is not found in maple wood. The application of the varnish on the radial surface diminishes the hydrophobic characteristics of the spruce wood. In maple wood, the difference between the longitudinal and radial samples is very small (2%).

Key words: resonance wood, surface energy, coating, violin.

1. INTRODUCTION

So far, questions have been asked about the secret behind the production of violins of a special quality, whose performance is supposed to be given by the quality of wood used, the type of construction and implicitly by the lake used to extend the life of the violin [1–2]. On the other hand, [3] he claims that the secret of the famous violins is attributed to the way the wood is processed and, in particular, to the technological grinding operation which corrects all the irregularities of the previous processing. One of the most important Romanian violinists, specialized in repairing and building musical instruments, Roman Boianciuc, in his publication entitled "Personal communications on the quality of attempted violins", believes that the secret of the famous violins is attributed to the lake used, supporting the hypotheses made by Stradivarius according to which the type of lake used represents the great secret of the violins. Schelleng [4], in his research, provides accurate data on all types of varnishes used so far, from parquet varnishes to the finest lakes used on famous violins, for which determined Young's modulus and loss factors. He claims that for every type of varnish used on musical instruments, in all cases experienced, if the varnish penetrates deep into the wood, it greatly degrades the resonant qualities of musical instruments, especially violins. [1] refers to the problem of discovering the secret of famous violins whose musical performances have not changed over the years, putting this performance on the basis of the Cremonese lake applied by various methods, which aims to extend the life of famous violins and maintaining their sound quality. However, [2] he believes that the value of a violin is given by the resonance index of the violin, in the range 196-659 Hz, an index that corresponds to the fundamental sounds of the strings. In order to highlight the changes that occur as a result of the priming and varnishing effect, studies and research were carried out by applying a thin layer of varnish on maple and spruce wood samples for which the contact angle, surface energy was determined, polar component and dispersive component.

2. MATERIALS AND METHOD

2.1 Materials

In this study, two sets of wood species were analysed: maple wood and resonant spruce. From each species two categories of samples were analysed according to the orientation of the wood fiber and the annual rings with respect to the longitudinal axis of the samples: the longitudinal ones marked with L have the longitudinal axis parallel to the fiber direction, and the radial ones marked with R have the longitudinal axis of the sample perpendicular to the fibers, being oriented radially with respect to the annual rings. The samples were extracted from the already finished violin plates, having a varnished surface (the one outside the violin) and an unvarnished surface (the one inside the violin body). The samples were purchased from the musical instrument factory S.C. Gliga Instrumente Muzicale S.A. The varnish used is a laque based on natural resins and spirit, being applied in about 12 layers. The Figure 1 shows the analysed samples.

The geometric characteristics of the samples are presented in Table 1.

Table 1. The geometrical and physical features of samples

Samples	Thickness (mm)	Length (mm)	Width (mm)	Mass (g)
Maple 1R	3.008	50.28	10.51	0.9913
Maple 2R	3.024	50.27	10.45	0.9753
Maple 1L	4.048	50.08	10.1	1.2083
Maple 2L	4.032	50.3	10.3	1.2464
Spruce 1R	2.494	50.45	10.44	0.7086
Spruce 2R	2.736	50.04	10.05	0.691
Spruce 1L	3.02	50.53	10.37	0.8439
Spruce 2L	2.908	50.13	10.3	0.7012

a)

b)

Fig. 1. The varnished wood samples: a) spruce; b) maple

2.2 Methods

The evaluation of wood samples surface energy was carried out by the θ contact angle method that is a thermodynamic equilibrium resulting from superficial/interfacial free energies. The value of the contact angle depends on three factors:

-the morphology of the substrate expressed by the superficial tension between the solid - gas medium (γ_{SG} *mN/m);*

-the nature of the liquid expressed by the superficial liquid - gas tension (γ_{LG}, *mN/m*);

- the nature of the liquid - substrate interactions expressed by the superficial tension between the solid - liquid medium (γ_{SL}, *mN/m)*, according to the relation (1).

A liquid placed on a solid surface, in the absence of gravitational forces, will take the shape corresponding to the minimum energy of the system [5–7]. This occurs when:

$$\gamma_{SG} = \gamma_{SL} + \gamma_{LG} \cos\theta \quad (1)$$

where γ_{SG} – solid – gas superficial tension, γ_{SL} – solid – liquid interfacial tension, γ_{LG} – the superficial tension of the liquid in contact with its vapors, all in [*mN/m*], θ - contact angle (the angle of the tangent to the liquid-gas surface in the contact point of the liquid-solid interface).

The contact angle may take values between 0 and 180°. If the contact angle θ <90° (polar surface), the material is hydrophilic (it absorbs the liquid), and if θ> 90° (scattered surface), the material has a hydrophobic character (it does not absorb liquid) (Figure 2). The type of interaction between that surface and the liquid used in the analysis can be estimated in function of θ angle [7, 8].

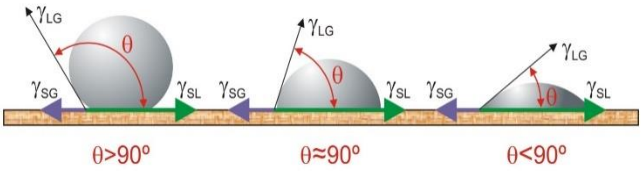
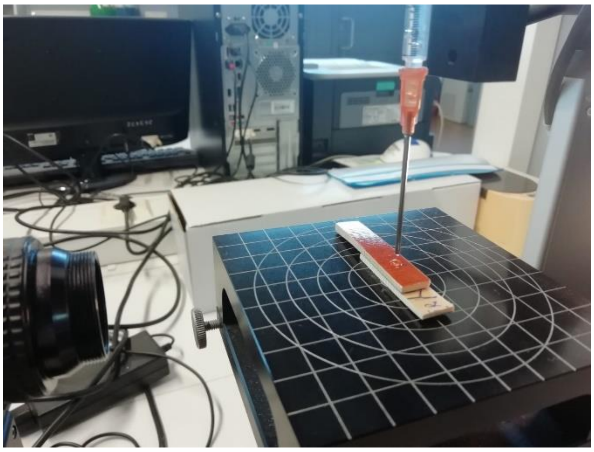
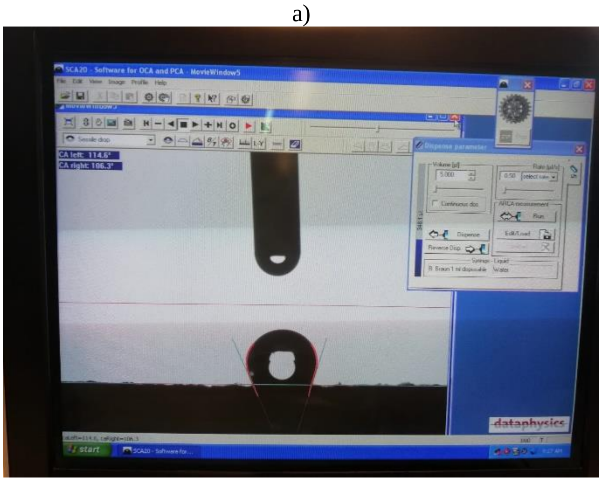


Fig. 2. The measurement of the contact angle [7, 8]

The contact angles were measured by the hanging drop method using System OCA-20 equipment (Data Physics Instruments - Figure 3). A syringe with water and one with ethylene glycol were successively placed on top of all specimens. One drop with a volume of 10 μL of sample liquid was dropped from each syringe with rate of 0.5 $\mu L/s$. The angle formed by droplet and specimen surface has been measured. The sample is placed between a light source and a recording camera (Figure 3, b). The measurements have been carried out at room temperature and normal humidity conditions (T = 22.7°C and RH=65%). Taking images at every second, dynamic studies of the contact angle changes allow the evaluation of absorption/ adsorption capacity of the specimens. The measurement procedure was applied to both the lacquered surface and the unpainted surface of the samples in order to analyze comparatively the surface energies of the two wooden surfaces (lacquered and unvarnished).



a)

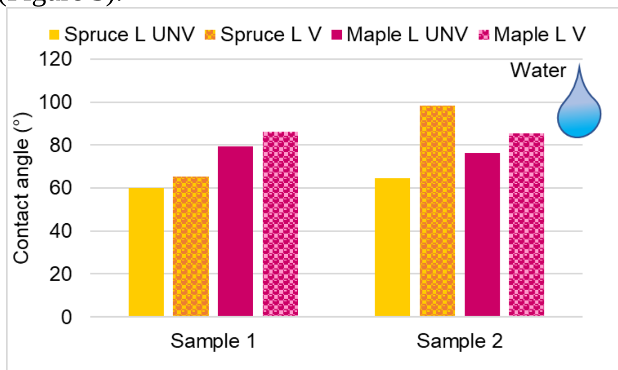


b)

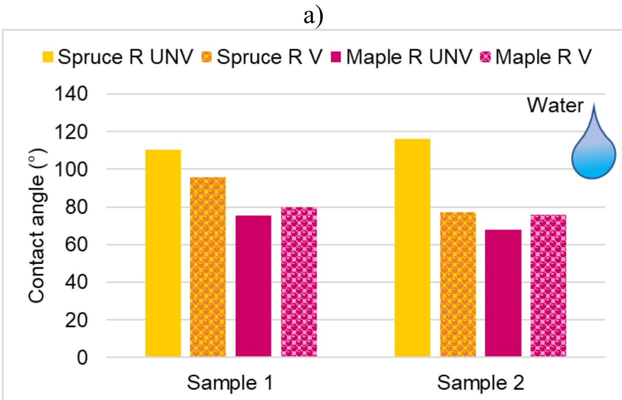
Fig. 3. The experimental determination of the contact angle

3. RESULTS AND DISCUSSIONS

The size of the contact angle differs depending on the investigated surface (lacquered - unvarnished), but also on the direction of cutting the wood (longitudinal - radial) and wood species, as can be seen in Figure 4. Depending on the liquid used in the test, the contact angle differs for the two types of species and for the two cutting directions relative to the wood grains. In the case of spruce wood, the following aspects are observed: the contact angle is higher for radially cut samples than for longitudinal ones (Figure 4, a and b). In the longitudinal direction, the lacquered samples have a larger contact angle than in the radial direction. A similar behaviour is found for both types of liquid used in the test. For maple wood samples, the following observations can be highlighted: depending on the liquid used, the contact angles differ between the finished and unfinished samples. Thus, the value of the contact angle in the water drop test is higher for the finished surfaces than for the natural ones, while in the case of using ethylene glycol, the behaviour is reversed (Figure 4, c and d). In the radial direction, the value of the contact angle is less than in the longitudinal direction in the case of maple wood. The surface energy registers considerably higher values (approximately 6-8 times) in the longitudinal direction for the spruce wood samples, finished-unfinished and the finished maple wood samples. Interestingly, the surface energy of unpainted maple samples, cut in the radial direction, is 4 times higher than in the longitudinal direction
(Figure 5).



a)



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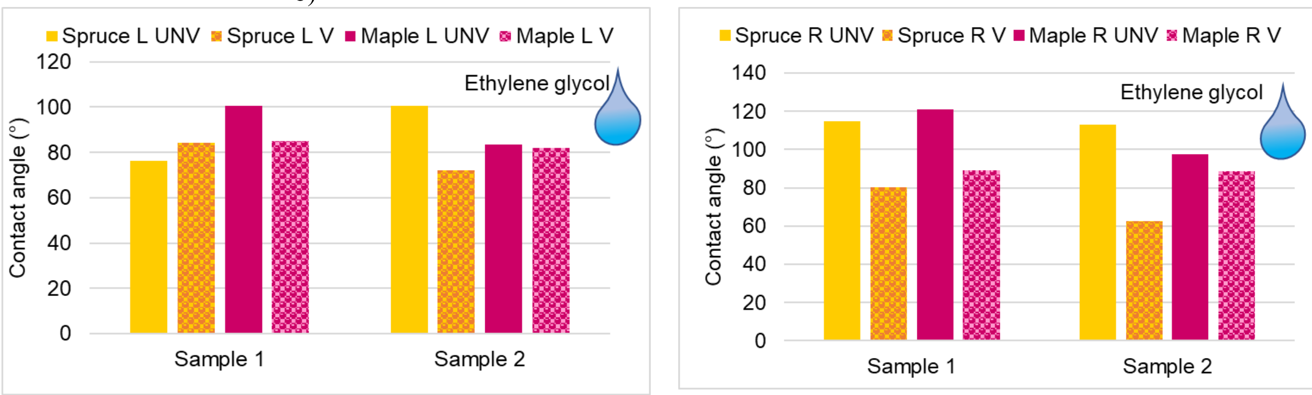
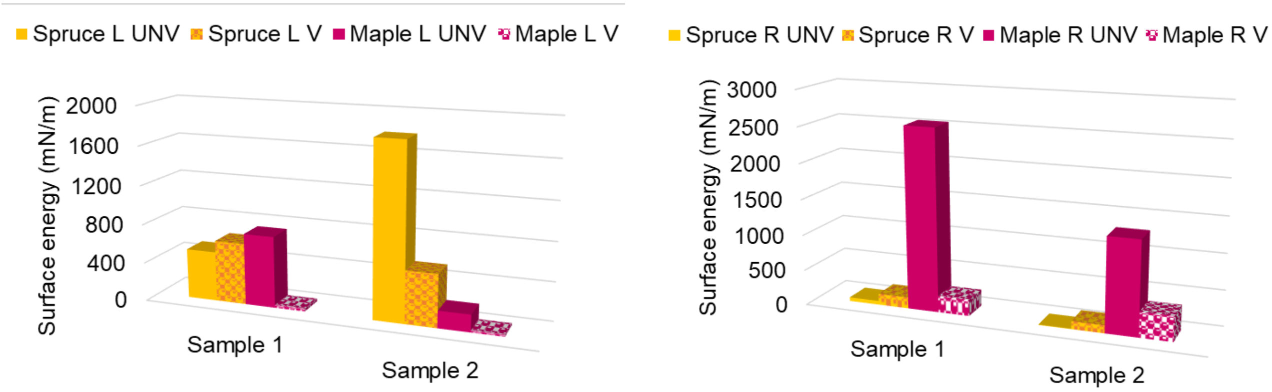


c) d)

Fig. 4. Variation of contact angle in accordance with different samples: a) samples cut in longitudinal direction, water drop; b) samples cut in radial direction, water drop; c) samples cut in longitudinal direction, ethylene glycol drop; d) samples cut in radial direction, ethylene glycol drop



a) b)

Fig. 5. Comparison between surface energy in accordance with different samples: a) samples cut in longitudinal direction; b) samples cut in radial direction

4. CONCLUSIONS

The paper aimed to identify differences in the surface energy of wood surfaces depending on the species, the cutting direction (anatomical features) and the contact fluid. Modification of the wood surface by varnish-like coatings leads to changes in the surface energy of the material.

The most important results highlight:

•the surface energy of the spruce wood samples decreases after the application of the varnish by approximately 50% in the case of longitudinally cut samples and increases by approximately 139% in the case of radially cut samples.

•In the case of maple wood samples, the behaviour differs from that of spruce wood. Thus, the surface energy decreases after the application of the varnish by approximately 94% in the case of samples cut longitudinally and by approximately 84% in the case of samples cut radially.

•the surface energy of spruce wood without surface treatment is 60% higher than that of maple wood, in the longitudinal direction.

•in radial direction, maple wood has a surface energy approximately 34 times higher than spruce wood.

•In the case of lacquered samples, the surface energy of maple wood samples is 95% lower than in the case of spruce wood, cut longitudinally.

This influences the acoustics of the musical instrument both by changing the angles of reflection and dispersion of sound waves and by traversing sound waves through environments with different properties.

5. ACKNOWLEDGMENTS

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