

Wood and varnish analyses in contemporary violin making

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Summary

The acoustic properties of the wood and varnish are super important for the sound quality of violins, violas, and cellos. Good varnish boosts the instrument's sound, while bad varnish inevitably ruins its acoustic potential. Decades of chemical testing and acoustic experimentation in the Master Workshop for Violinmaking Martin Schleske have contributed to uncovering the tonal promise of violin varnish and thus the secrets of violin sound. In violin making, it makes sense to use acoustic methods to examine both the quality of the tonewood used and the tonal influence of the violin varnish.

ANATOMICAL ANALYSIS OF WOOD

In the laboratory of Martin Schleske's master violin-making workshop, both acoustic and anatomical analyses of violin wood are carried out. In addition, acoustic analyses of the varnish formula provide information about the extent to which the violin varnish used is suitable for enhancing the sound of the instrument.

While acoustic analysis quantifies the tonal suitability of the tonewood, anatomical analyses reveal the reasons for the observed differences in quality between different tonewoods. In collaboration with the University of Munich, we carried out numerous wood anatomical analyses using scanning electron microscopy.

The thematic focus was on comparing contemporary tonewood with that of the famous old Italian masters of the 18th century.

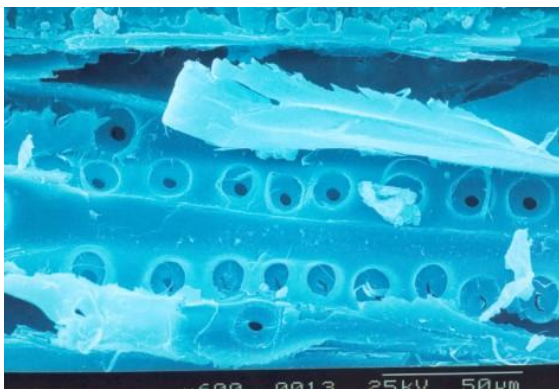


Fig. 1: Wood analysis using a scanning electron microscope. Images of spruce wood from a ceiling by the Neapolitan master F. Gagliano from 1780.



Fig. 2: View of the court dots in the tangential side walls of two tracheids. Magnification 2000x. The missing torus in the center of the court dot is clearly visible. The dot membranes are preserved. Investigating this question was one of the reasons for performing the SEM analysis.

ACOUSTIC ANALYSIS OF WOOD

The key parameters for the acoustic characterization of violin wood are:

- the speed of sound of longitudinal waves along and across the grain
- the density
- the vibration damping along and across the grain

These parameters are determined in our workshop using resonance analysis. The speed of sound of longitudinal waves parallel to the grain in spruce wood is between 4800 and 6200 m/s. The density is between 350 and 420 kg/m³. The quotient of these two parameters provides an initial indication of how the violin top should be crafted in terms of thickness distribution.

ACOUSTICS OF VIOLIN VARNISH

Even more noticeable than the variations in wood quality are the acoustic differences between different varnish formulations.

An excellently crafted instrument can be ruined in terms of sound by the wrong primer or varnish. Here, it is particularly important to note the strong dampening effect of numerous substances and formulations. On the other hand, an optimal varnish can enhance the sound of a well-crafted instrument, as the varnish has an influence on its modulatability and response.



Fig. 3: Analysis of different paint substances on sample wood strips in our laboratory.

Given the wide range of tonal possibilities offered by the finish, we have spent the last few years researching the acoustic influence of over 300 different lacquer treatments – always with the aim of developing and refining recipes.

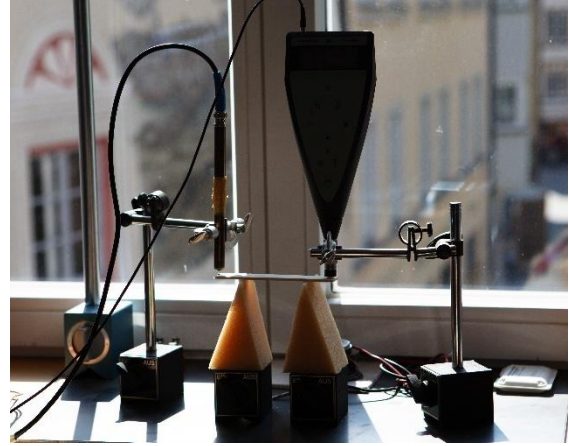


Fig. 4: Test setup for determining the acoustic quality of violin varnish. The test strips are set into vibration electromagnetically. The vibration response is recorded by a measuring microphone and evaluated using Fourier transformation.

By measuring primed and varnished sample strips, it is possible to determine the extent to which the individual treatments (formulations, individual substances, application techniques, absorption depth, etc.) change the acoustically relevant properties of the wood. From this, conclusions can be drawn about the gradual benefit or damage of the treatment to the sound of the instrument. In this way, the varnishing and treatment can be optimized.

As a general rule, a dampening effect on the wood should be avoided. In the time domain, damping is inversely proportional to the decay time of the vibration. A strongly damped vibration sounds “dull” because the decay time is short. In the frequency range, the damping is proportional to the resonance peak width – the so-called half-value width. A slightly damped resonance has a steep and high resonance peak in the frequency range, while a strongly damped resonance has a broad and flat resonance peak.

Fig. 6 shows the result of an acoustic paint analysis. The transmission function $FRF = a/F(f)$ is shown: acceleration a over force F as a function of frequency f . The frequency response of the first bending natural vibration is plotted as the resonance peak. A comparison of this resonance peak before and after treatment shows the (in this case unfavorable) effect of the test coating carried out here: a significant dampening can be observed.

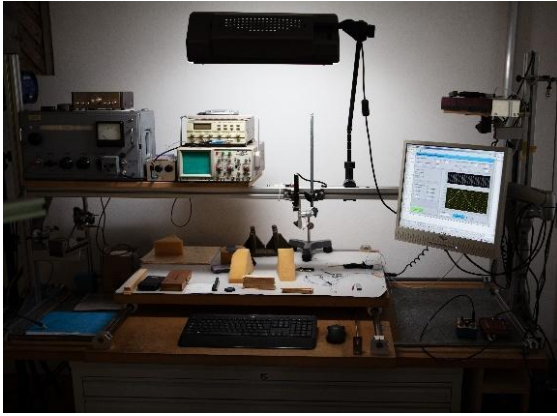


Fig. 5: Measuring station for determining the acoustic quality of violin varnish in Martin Schleske's master violin-making workshop.

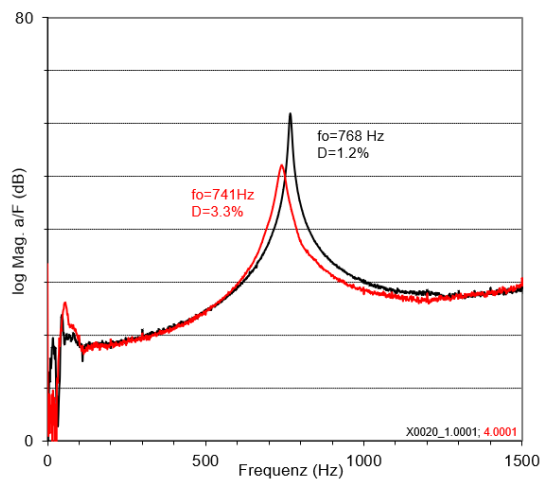


Fig. 6: Investigations into the acoustic effect of a coating by measuring the transfer function of a freely mounted sample strip and evaluating the resonance of the first bending natural vibration. Measurement of the untreated strip: black; measurement of the coated sample strip: red.

The change in the resonance peak shows that the coating examined here has an acoustically unfavorable effect:

The damping of the resonance was significantly increased. This can be seen from the fact that the resonance peak of the coated strip has a much larger half-width at the same level drop. The speed of sound has been reduced. This can be seen from the fact that the resonance frequency of the varnished strip has shifted towards lower frequencies. A varnish with this kind of acoustic effect should not be considered for varnishing a violin.

If the varnish shown were to be applied not only to a test strip but also to the white instrument, this would have undesirable consequences in terms of sound:

additional damping means a reduction in the acoustic efficiency of the resonances. This would significantly reduce the instrument's dynamics, carrying power, and tonal strength.

Furthermore, because an increase in damping due to priming or lacquering reduces the level differences between resonance peaks and resonance troughs and broadens the bandwidth of the individual resonances, an increase in damping means that both the sensitivity of the instrument to the musician's vibrato and the instrument's modulability are impaired.

In numerous analyses, we have found significant differences in the damping behavior of various primers and varnishes. The range is between 0.75 times and 3.0 times that of untreated wood. This means that some formulations allow a reduction in the damping of the wood of up to 25%, while other substances triple the damping of the wood. This makes it clear that the choice of varnish can make or break the success of the instrument being made.

In addition to the change in damping caused by the coating, the change in sound velocity is of particular importance. The speed of sound results from the ratio of elastic modulus to density. The elastic modulus determines the stiffness of the structure together with its geometric dimensions. Wood treatments, primers, and coatings can affect the elastic modulus of the wood by strengthening or weakening the fiber structure.

In practice, the question arises as to whether the chosen treatment leads to an undesirable increase in the vibrating mass, as the substance is merely introduced into the vessels of the wood structure as a “burdening” ingredient, or whether the treatment leads to a desirable increase in elasticity by strengthening the fiber structure. This question is answered quantitatively by our varnish analyses.

An increase in sound velocity indicates that the “strengthening” effect of the treatment carried out outweighs the “stressing” effect. The wood treatment should not result in a reduction in sound velocity under any circumstances, as this would mean that the panel would have to be made thicker than it would be without varnishing in order to achieve the same natural frequencies. Some unfavorable coatings impose this requirement on the panel design. On the other hand, primers and coatings have also been investigated that allow relatively thin panels to be used, as the wood treatment shifts the resonances to higher frequencies due to its positive effect on the speed of sound.

An example is shown in Fig. 7: Numerous resin solutions were examined in terms of their influence on the sound velocity and damping of the wood.

Depending on the resin, considerable differences were found (internal research results).

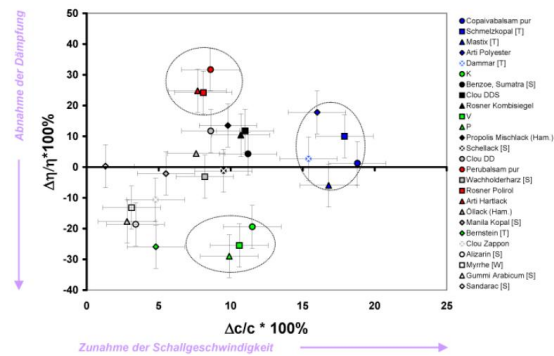


Fig. 7: Influence of different resin solutions on the acoustic properties of tonewood for violin making. The changes in sound velocity (x-axis) and damping (y-axis) of spruce wood strips are shown.

The changes in sound velocity and attenuation were measured after a drying period of nine years. The substrate material was spruce wood strips with a thickness of 3.0 mm and a grain running perpendicular to the length of the strips. The acoustic influence of the resin solutions was even greater on thinner strips.

The horizontal axis, labeled $\Delta c/c \cdot 100\%$, shows the increase in sound velocity as a percentage compared to untreated wood. The further to the right the data points are, the greater the increase. The increase in sound velocity ranges between 0 and 20%. The resins and substances listed in the legend are arranged according to the increase in sound velocity they cause, led by copaiba balsam (+18.8% compared to untreated wood).

The change in damping is plotted on the vertical axis labeled $\Delta \eta/\eta \cdot 100\%$. The increase or decrease in damping here is between +40% and -40% compared to untreated wood.

The blue data point group is characterized by a significant increase in sound velocity with a relatively small change in damping; the green data point group shows a slightly lower increase in sound velocity, but at the same time a stronger damping effect; the red data group shows a significant increase in damping; the unfilled data points in the zero point range show a slight change in the acoustic properties of the untreated wood.

Although numerous substances investigated do not yet represent mixture combinations, i.e., no varnish formulations from different substances, there are already considerable differences between resins. Another interesting finding is that the effect of the individual substances does not allow any predictions to be made about a coating produced from them—the

coating formulations behave acoustically differently than the sum of their individual components.



Abb. 8: Trocknung und Bestrahlung der unterschiedlich behandelten und lackierten Probeholzstreifen.

Fig. 8 shows some of the sample wood strips treated in our coating laboratory during drying by means of UV irradiation.



Fig. 9: Two classic varnish resins before dissolving in turpentine oil or alcohol.

Measurements of several samples allow the parameters most favorable for the acoustic success of the coating to be optimized. Such parameter studies can provide helpful answers to the following questions:

- The most acoustically favorable mixing ratio for a formulation
- The most acoustically favorable concentration
- The most acoustically favorable absorption depth of the substance – and thus information on the application technique (cloth, brush, etc.)
- The most acoustically favorable layer thickness – and thus information on the acoustically favorable number of coating layers.
- Acoustic differences with different panel finishes
- The most acoustically favorable structure in terms of sensible intermediate steps or intermediate layers
- Temporal changes in the paint finish and thus long-term acoustic influence



Fig. 10: Production of custom pigments in our laboratory.

Our research into these questions has shown that:

- Some varnishes demonstrate acoustic superiority over other varnishes on thin wood thicknesses (2.0 mm), but this is no longer the case on thicker wood thicknesses (3.0 mm). In this respect, the acoustic benefits of the varnish used are clearly linked to the respective panel design of the instrument.
- With some varnishes, the first coats bring a clear acoustic benefit, while subsequent coats of these varnishes significantly reduce the benefit achieved. In contrast, varnishes were examined whose first coats brought a comparatively lower acoustic benefit, but whose acoustic benefit increased with further coats.
- Some primers are acoustically useful when applied superficially, but ruin the wood acoustically once they penetrate beyond a certain depth. This proves the importance of a suitable pore filler for this type of primer.
- Certain intermediate layers prove to be unfavorable in the structure of a paint finish. Although the primer itself had a favorable acoustic effect, a subsequent intermediate layer applied before the actual build-up of the paint layers negated this positive influence.

The observations mentioned above are only examples of some internal parameter studies. They show the importance of careful handling of the parameters relevant to the acoustics of violin varnish. The recipe itself is only a small part of the truth. For the violin maker, the optimization of these parameters is one of his essential tonal competencies.

LITERATURE

For further reading: Martin Schleske: “On the Acoustic Properties of Violin Varnish.” CAS Journal Vol. 3, No. 6, (Series II), November 1998.

For theoretical background: Martin Schleske: “Empirical Tools in Contemporary Violin Making: Part II: Psychoacoustic Analysis and Use of Acoustic Tools.” CAS Journal Vol. 4, No. 5 (Series II), Nov 2002).



Varnishing a recently completed violin in the varnishing room of Masterstudio for Violinmaking Martin Schleske.