Changes in vibrational properties of coated wood through time from application of varnish, with recipes used in European or Iranian string instruments making

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Abstract

The influence of vanishing process on the vibrational properties of the wood+coating systems was studied using different types and recipes of instrument-making varnishes, used in traditional Iranian string instruments making, or in European violin-quartet making. The focus is on the time evolution of these properties, that can be involved in the changing behaviour of newly made instruments. The different tested varnishes recipes were applied on wood representative of each culture, studied both along-the-grain and cross-grain, and monitored through time for up to more than one year. The different effects, both immediate and their kinetics through time after application, are discussed.

1. Introduction

Surface finish is usually one of the last steps in instrument making. Depending on types of instruments, as well as on cultures, wood finish can consist of different processes. In stringed instruments, in many cases, wood is coated, which can be done with different products, including a wide variety of varnishes. Although the primary goal is probably more related to protection and/or aesthetics, varnishes can also affect the vibrational properties. The acoustical effects of several violin-making varnishes has been analysed regarding their significances in regard to instrument behaviour [Schelleng 1968] and to the diversity of ingredients and combinations found in historical recipes [Schleske 1998]. These studies noticed the evolution through time (years) after varnish application, however the ambient humidity conditions were not regulated, although they have a strong influence [Brémaud & Gril 2015], and/or the steps or measurement were not very detailed over time. Fine kinetics of changes in vibrational properties were analysed in the case of some more industrially used varnishes (Minato et al. 1995) or in the case of the oriental laquer Urushi [Obataya et al. 2001, 2002]. However, different types of coatings or varnishes, due to their different chemical nature, should show different effects on the wood+coating properties [Simonnet et al. 2002], as well as different kinetics of changes during time after application. These changes through time are possibly related to the opinions about changing response of newly built instruments. The objective of the present work is to analyse the detailed kinetics of these changes, starting from the different steps of the varnishing procedure, and followed over long times in controlled climatic conditions. The study includes violin-making as well as Iranian instruments making varnishing processes.

2. Materials and Methods

Studied material included wood+coating systems that are representative of European, and Iranian, traditions of instrument making. The wood species were White Mulberry (Morus alba) and Spruce (Picea abies). Material for both species was selected as high-grade for instrument making. 184 specimens (for Spruce) and 96 (for Mulberry) specimens were prepared, in the longitudinal (L) and radial (R) directions of wood. After measurements of the untreated physical and vibrational properties, they were distributed into matched groups of (6L+6R) specimens each through a careful statistical procedure. Each group is intended for a different modality of the varnishing process: 12+10 groups for Spruce+Violin making varnishes, 5+3 groups for Mulberry+Iranian long-necked lutes making varnishes.

Vibrational properties were measured by non-contact forced vibrations of free-free bars, using the device and protocol described in [Brémaud 2006; Brémaud et al. 2012]. They included longitudinal and radial specific modulus of elasticity (E'/γ, proportional to resonance frequencies) and damping coefficient ($\tan\delta$, related to vibration decay and to the sharpness of resonances also called quality factor).

Tested varnishing procedures and recipes were as follow:

-Spruce was coated according to varnishing procedures used in violin making. 3 kinds of ground layers were tested. 5 recipes of siccative-oil based varnishes were applied, using different oils and resins and proportions. All the steps of application and curing (by UV-light) were done inside a climate-regulated room. The changes in mass and in vibrational properties were monitored during all steps, and then followed during more than 12 months after application (still in progress).

-Mulberry was coated by alcohol-based sandarac varnish, following the same step-by-step monitoring through time, in regulated conditions, as above. Solvent alone, and 1, 3, 6 varnish layers were tested. Monitoring of changes in properties was conducted for about 8 months.

-An additional study on Mulberry was based on actual application by a skilled Tar and Setar maker of 3 different varnishes (2 alcohol-based: Sandarac and Shellac, and 1 artificial: polyester). Application was conducted in the workshop, then properties were measured in lab-conditions after 2.5 and 7 months.

3. Results and discussion

After applying on mulberry wood a single layer of Sandarac/ethanol varnish, the resonance frequency was barely affected in L direction but clearly increased in R, and damping was increased by up to 50% in both R and L (Figure 1). Ethanol solvent alone had very limited effect. With 6 layers (similar to actual instrument making), immediate effects were an increase in frequency in R (+6%) and very strong increase in damping (+100 in L to +160% in R). Over time, frequency continued to increase while damping re-decreased, starting to stabilize only after 2 months. Sandarac-ethanol varnish appears to have, when stabilized or “dry” -which took about 7months- a stiffening effect with nearly no final increase in damping. Workshop application by a skilled maker gave similar results for Sandarac and for Shellac, while polyester proved to induce a more permanent increase in vibration damping.

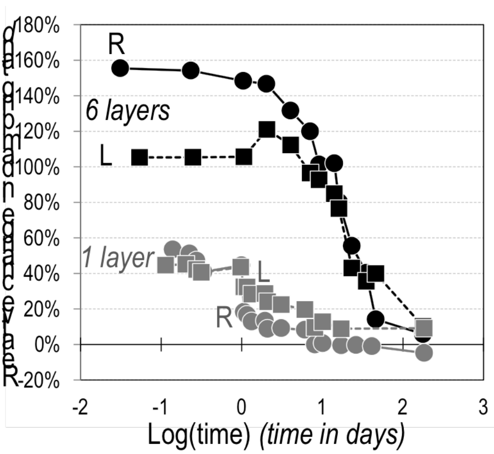

Figure 1: Changes trough time (7months) of vibration damping of mulberry wood varnished with Sandarac dissolved in ethanol. 1 data point = mean of 6 specimens, Time axis in Log-scale (0=1day, 1=10days, 2=100days).

The effects of application on spruce wood of violin-making varnishes is illustrated, in Figure 2, by the example of a linseed-oil + Sandarac resin varnish. The vibrational properties changed little just after application, when varnish is still quite liquid. After UV-accelerated curing, damping is very strongly increased (+40% to +80% in radial direction) for a single layer of varnish applied. On Spruce, the differential of effects between along the grain and cross-grain is much more pronounced than on Mulberry. The protocol we designed allows to separate the effects of varnish itself from effects of moisture changes (due to UV or to slight de-regulations of climatic room). One thick layer of varnish evolves much more slowly than a thin one. Changes in damping are only partially related to added mass of varnish: 2 thin layers result in more added mass than 1 thick layer, but has similar effects on vibration damping. The kinetics of changes in properties after coat-

ing with siccative-oil based varnish is obviously much slower than the previous example on alcohol-based varnish. With this example of “fatty” varnish, the properties continue to evolve, without yet clear signs of stabilization, after one year from initial varnishing. The monitoring of changes in properties through time is intended to be continued for several years.
To complete the example described here, the presentation will compare the same protocol and obtained results with 5 different kinds of “siccative oil + resins” violin-making varnishes.

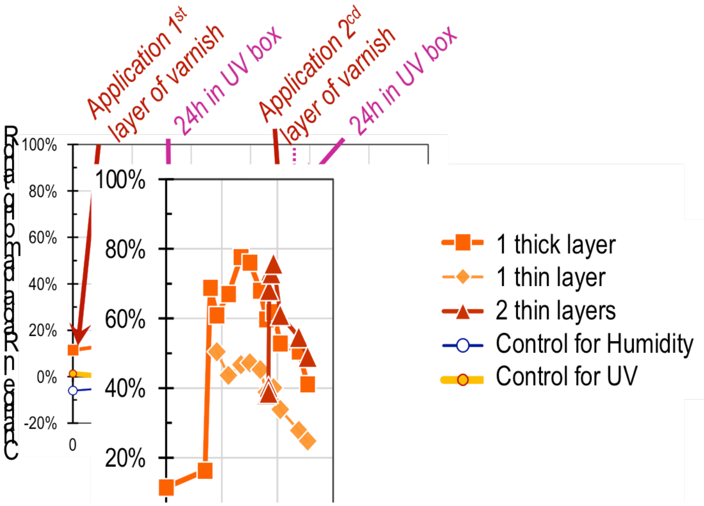

Figure 2: Changes trough time (12months) of vibration damping of spruce wood coated with a “fatty” varnish (Sandarac resin and linseed-oil). 1 data point = mean of 6 specimens, Time axis in Log-scale (0=1day, 1=10days, 2=100days).

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