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EFFECT OF TRANSITIONAL MOISTURE CHANGE ON THE VIBRATIONAL PROPERTIES OF VIOLIN-MAKING WOOD

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Introduction

Wood is a very hygroscopic material. When submitted to different relative humidity (RH), which can typically be the case when an instrument is played in different places, the internal moisture content of wood will be changed. This is well known to result in dimensional swelling or shrinkage, and will also modify the wood mechanical or acoustical properties. The equilibrium moisture content (EMC) dependence of vibrational properties (specific modulus of elasticity E'/γ which is related to resonance frequencies, and damping coefficient $\tan\delta$) has been well-studied for spruce wood along the grain [Obataya et al. 1998] and for various wood species in the three main directions of wood [Suzuki et al. 1980]. However, equilibrium state is only reached after a relatively long time (weeks), whereas the humidity changes encountered when an instrument is played in different places involve short time scales (hours) and are typically out-of-equilibrium. Previous research have shown the existence of transitional effects, notably on damping [Sasaki et al. 1988; Hunt and Gril 1996]. However these studies considered a single direction of anisotropy each, and wide steps of changes in relative humidity. The present work aims at observing transitional moisture effects on vibrational properties of violin-making woods (spruce and maple) over different steps and different histories of RH changes, in longitudinal and radial directions of wood.

Materials and methods

Material of Norway spruce (*Picea abies* [L.] Karst.) and of sycamore maple (*Acer pseudoplatanus* L.) was selected in order to reduce natural variability within the tested sampling. Longitudinal ($12 \times 2 \times 150 \text{ mm}^3$, $R \times T \times L$) and radial ($150 \times 2 \times 12 \text{ mm}^3$, $R \times T \times L$) specimens were prepared with a fine planed surface. They were separated in 3 groups corresponding to 3 protocols of humidity changes:

-Adsorption: samples were first oven-dried (48h at 60°C followed by 2h at 103°C), then stored in a desiccator for 2 weeks, then at 20°C and 35%RH,

50%RH, 65%RH, 85%RH, for at least 3 weeks each time. 8 radial and 8 longitudinal samples for each species served to measure properties at equilibrium, while 2 radial and 2 longitudinal for each species served to monitor transitional changes.

-Desorption: samples were first immersed in water for 3 weeks, then stored (3 weeks or more until stable) at 85% RH, 65% RH, 50%RH and 35%RH. Same protocol/number of specimens as above.

-Various humidity paths: 18 radial and 18 longitudinal specimens of each species were used to explore transitional changes with all possible steps between the above RH conditions.

Vibrational properties were measured by non-contact forced vibration of free-free bars using a device and software developed at LMGC [Brémaud 2006; Brémaud et al. 2012]. Specific dynamic modulus of elasticity E'/γ and damping coefficient $\tan\delta$ were measured at first resonance frequency in bending. Repeatability tests indicated an experimental error of $\leq 2\%$, and a point of measure could be taken every ≤ 1 minute.

Results and discussion

The equilibrium moisture content at different RH, as well as the hysteresis/difference between adsorption and desorption, was comparable between spruce and maple (Table 1).

EMC(%) at RH:	35%RH	50%RH	65%RH	85%RH
Spruce/adsorption	5.5	7.9	10.4	17.4
Maple/adsorption	5.6	8.1	10.3	17.3
Spruce/desorption	7.1	10.1	13.1	20.5
Maple/desorption	6.9	10.1	13.3	21.1

Table 1: Equilibrium moisture content (EMC, measured after ≥ 3 weeks in stable conditions) of spruce and maple at different RH conditions.

Regarding moisture dependence of vibrational properties at equilibrium (Figure 1), the general trends were comparable to previous results [Obataya et al. 1998]. The differences between adsorption and desorption were small (once taken into account the hysteresis in EMC), with the exception of longitudinal damping in maple (maybe due to some extraction during water saturation). Damping in maple was slightly less affected by

high moisture than for spruce. Mostly, properties in radial direction were clearly more modified by elevated moisture than in longitudinal direction, resulting in a strong increase in the degree of anisotropy.

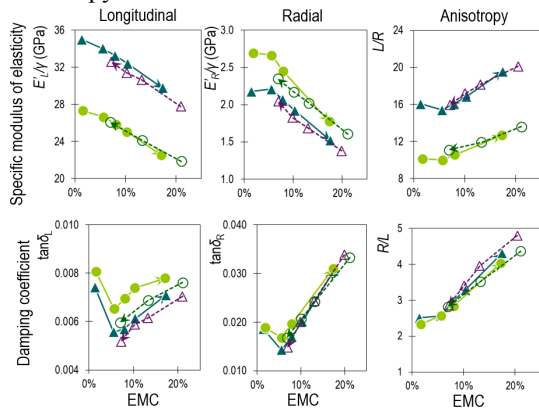


Figure 1: Dependence on Equilibrium moisture content EMC of specific modulus and damping and their longitudinal/radial anisotropy. (Triangles) spruce; (circles) maple; (filled symbols) adsorption; (open symbols) desorption.

When changing conditions of humidity, frequency and dimensions evolved together with internal moisture content of wood. On the contrary, a transitional increase in damping was always observed, whether the humidity decreased or increased (Figure 2). The peak value of this increase in damping occurred from 30 minutes to a few hours after changing conditions (depending on RH steps and direction of specimens). Then damping slowly decreased when evolving towards equilibrium state, which took 2-4 weeks, that is, after moisture content itself was stabilized. Moreover, this transitional increase in damping had a bigger amplitude when smaller steps in ambient RH were applied (Figure 3). For relatively small RH steps (e.g. 35-50% RH or 50-65% RH), transitional changes in damping clearly exceeded the differences between initial and final equilibrium values.

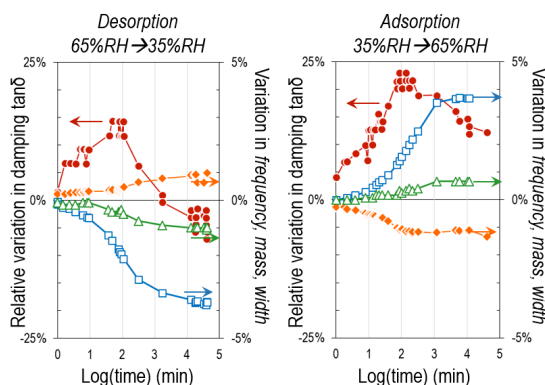


Figure 2: Example of transitional variations in (circles) damping, (diamonds) frequency, (squares) mass and (triangles) radial dimension, along time after changing RH conditions. Longitudinal spruce specimens.

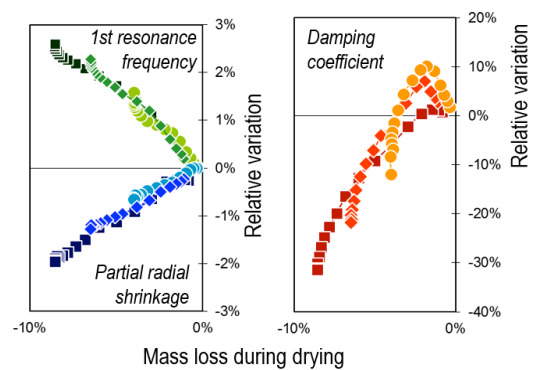


Figure 3: Relative variation through time in resonance frequency, shrinkage and damping plotted against mass loss during desorption from 85%RH to (circles) 65%RH; (diamonds) 50%RH; (squares) 35%RH. Longitudinal spruce specimens.

Conclusion

Differences in equilibrium moisture conditions reduce specific modulus of elasticity and increase damping, as is well known. Their anisotropy between longitudinal and radial direction is even more affected, which should modify vibration modes of instruments' plates. The transitional increase in damping occurring within a time scale of one/few hours seems even more relevant to instrument playing conditions, all the more so that its amplitude is more pronounced over smaller differences in RH, typically in the range of 35-65% that could be encountered in normal concert places.

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