

EFFECTS OF CONTINUOUS VIBRATION ON THE DYNAMIC VISCOELASTIC PROPERTIES OF WOOD

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Introduction

Many musicians believe that the quality of wooden musical instrument is improved by playing. Such a “playing effect” is recognized in stringed instruments such as violins, as well as woodwind instruments such as clarinets. Although no convincing explanation has so far been given for that empirical knowledge, it is considered that the playing i.e. continuous vibration may affect the dynamic viscoelastic properties of wood.

The first systematic study on the playing effect was conducted by Sobue and Okayasu [1992]. They have precisely measured the dynamic Young’s modulus (E') and the loss tangent ($\tan\delta$) of 7 different wood species during continuous vibration. They have found that the $\tan\delta$ was significantly reduced by the vibration irrespective of wood species and the amplitude of vibration, whereas the E' remained almost unchanged. Subsequently Hunt and Balsan [1996] have reported that forced vibration involved slight increase in E' and reduction in $\tan\delta$. All those results indicate that the acoustic properties of wooden instruments can change by continuous playing. Sobue and Okayasu have speculated that certain internal stress was induced by the drying of green wood, and the relaxation of such “drying stress” was responsible for the significant reduction in $\tan\delta$ due to the vibration.

Figure 1 exhibits a simple viscoelastic model to explain the drying stress and its relaxation. When a green wood (A) is dried, hydrophilic amorphous polymers such as hemicelluloses and lignin are shrunk by the dehydration, whereas crystalline cellulose remains unchanged. Since the crystalline cellulose is much more rigid than the amorphous polymers, the shrinkage of amorphous polymers is restricted by the surrounding crystalline cellulose. Consequently certain internal stress is induced in the wood cell wall (B). As the amorphous polymers are frozen in dry state, the remaining stress and distorted conformation of the amorphous polymers remain unrecovered.

The effects of drying on the viscoelastic properties of wood have been studied well. According to Furuta et al. [1998], green wood shows single glass-

rubber transition at around 90°C, but additional transition appears at lower temperatures (50°C) when the wood is once dried and rewetted. That is, the distorted amorphous polymers are not relaxed unless they are hydro-thermally activated by boiling or steaming (heating in saturated water vapour), as shown in Fig.1 (B→A).

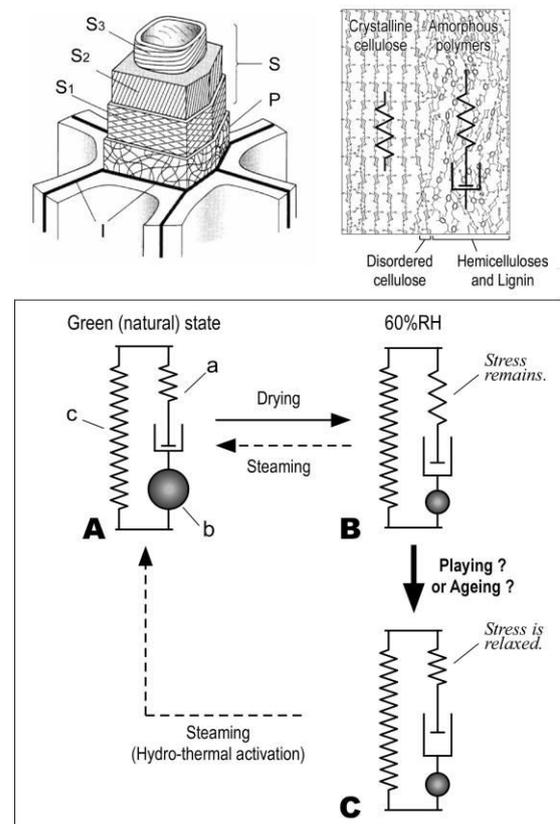


Fig.1. A viscoelastic model to explain the drying stress and its relaxation.

a, Viscoelastic part consisting of amorphous polymers; b, adsorbed water in the amorphous region; c, crystalline cellulose.

If the relaxation of drying stress is responsible for the changes in viscoelastic properties of wood due to continuous playing, no playing effect is expected in green wood or hydro-thermally treated wood where no drying stress remains or the remaining

stress is already relaxed. In many cases, however, the experiments have so far been conducted in dry condition, and therefore, the effects of drying stress are still unclear.

In order to discuss the influence of drying stress, we have tested the E' and $\tan\delta$ of spruce wood in saturated water vapour to prevent the samples from drying. Since green wood sample was not available, dry samples were steamed to relax the remaining drying stress, and the steamed wood samples were used instead of green wood.

Materials and Methods

Sitka spruce (*Picea sitchensis*) lumbers were cut into plates, 100 mm (L) \times 10 mm (R) \times 1 mm (T). One specimen was moistened at 100% relative humidity (RH) prior to steaming. The moistened samples were wrapped with moistened paper and enclosed in a plastic bag. The bag was then put in boiled water at 98°C for 3 minutes to steam the wood sample. Another dry specimen remained unmodified and conditioned at 25°C and 60%RH.

E' and $\tan\delta$ of the wood specimens were determined by cantilever method. An end of the specimen was held by a brass clamp and the other end was tapped using a small glass ball. The deflection of specimen was detected using a laser displacement sensor. The E' and $\tan\delta$ were calculated from the resonant frequency of the first mode and decrement curve, respectively.

The dry specimen was continuously vibrated by a magnetic driver at resonant frequency for 48 hours while its E' and $\tan\delta$ were measured at 24, 48, 72, 96 hours after starting the continuous vibration. The testing condition was kept at 25°C and 60%RH.

In the same manner described above, the E' and $\tan\delta$ of the steamed specimen were determined at 25°C and 100%RH. To keep the humidity around the sample, the equipment was installed in a closed box in which sufficient amount of water was placed in the bottom.

Results and Discussion

Dry specimen showed increase in E' and decrease in $\tan\delta$ during continuous vibration, and then these values remained unchanged. In contrast, the continuous vibration affected little the E' of steamed specimen. This fact implies that the playing effect is related to the relaxation of drying stress. On the other hand, the steamed wood showed decrease in $\tan\delta$ during vibration as dry specimen did. A possible reason for the reduction in $\tan\delta$ is insufficient relaxation of drying stress due to short steaming time (3 min.). Otherwise, certain

stress was additionally induced by the cooling after the steaming treatment, and such a thermal stress might be relaxed by the continuous vibration. Further detailed experiments are necessary to prove the contribution of drying stress.

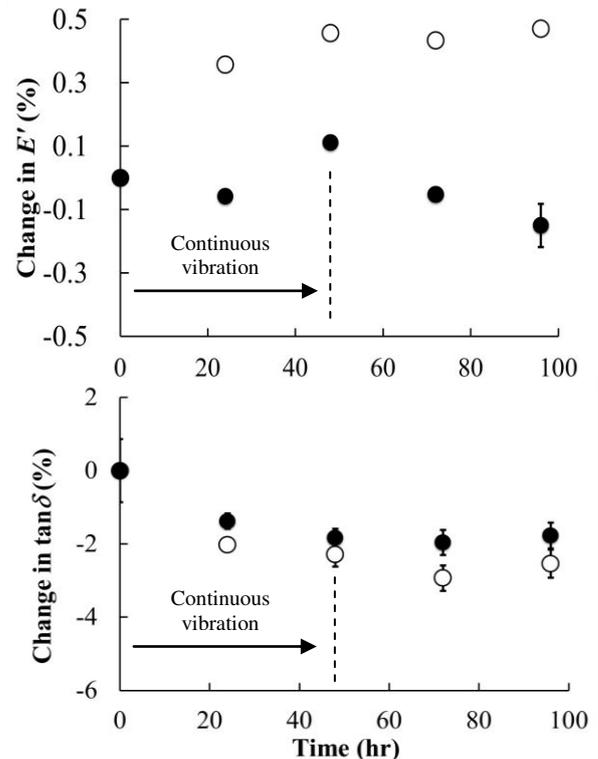


Fig.2. Change in E' and $\tan\delta$ plotted against the elapse of time. \circ , Dry specimen tested at 60%RH; \bullet , steamed specimen tested at 100%RH.

Acknowledgements

We are grateful to Aoyama Harp Co. providing spruce lumber used in this study. We also thank Dr.Sandie LeConte for her technical support.

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