Studies on the Vibrational Modal Analysis of Solid Woods for making the Violin – Part 2. The effects of coating materials on the resonant frequency of European spruce and maple

Woo-Yang Chung · Sun-Haeng Park*[1]

ABSTRACT

It was thought that the stiffness of a coated specimen became lower than that of the solid wood because the stiffness of the dried film of coating material is lower than that of the solid wood. The authors were trying to compare the effect of lacquer varnish and *rhus* lacquer on the resonant frequency of the solid woods for the violin, spruce and maple. Vibration modal shape of coated specimens were same to those of solid woods, but the frequency became lower at each mode as were expected regardless of coat. Frequency decrement of coated specimen was getting larger at upper mode in both European violin woods, however, *rhus* lacquer coated spruce specimens were less affected than lacquer varnish coated specimens.

Key words: violin, spruce, maple, modal analysis, resonant frequency, cutting direction, lacquer *varnish*, rhus lacquer

摘　　要

일반적으로 도막의 剛性은 목재의 剛性에 비해 낮으므로 도장된 소재의 강성이 백골재에 비해 낮아질 것으로 짐작할 수 있으므로 본 연구에서는 바이올린용 소재인 유럽산 가문비나무와 단풍나무에 투명래커와 전통옻칠을 도포한 후, 진동모드를 해석하고 공진주파수를 비교함으로써 수종별 도료 종류에 따른 음향특성의 변화양상을 분석하고자 하였다.

분석결과, 도장전후의 기본진동모드는 동일하였고 양 수종 공히 도료의 종류에 관계없이 도장재의 공진주파수의 감소가 확인되었으며 가문비나무의 경우, 모드가 증가할수록 주파수 減少幅이 증가하였으나 옻칠이 투명래커에 비해 그 감소폭이 적었다. 단풍나무의 경우에도 상위 모드에서 더 큰 주파수 감소를 나타냈지만 옻칠과 투명래커의 주파수 감소폭이 일정치 않았다.

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1. INTRODUCTION

Violin-family stringed instruments should be coated with appropriate coating materials to avoid the damage from the player's abrasion and heat as well as moisture and biological attack. Lacaquer varnishes have been widley used for the mass producive coating lines inspite of the low durability of the thick dried film which may affect the acoustical characteristics of the finished instruments.

Korean traditional *rhus* lacquer is famous for not only its' fantastic apperance but also tough and durable dried film and is used exclusively by the craft manufacturing masters. Chung et al.(1998) reported that it would be recommendable for the handcrafter to use *rhus* lacquer as coating material professional vioin-family instruments.

It was thought naturally that the stiffness of a finished specimen become lower because the stiffness of the dried film of finishing material is lower than that of the solid wood. And the difference in the penetrating power into wood of both coating materials and the properties of dried film might exist.

This analytical experiment was designed to observe the vibrational mode of coated wood specimens under bending moment created by impact hammer and to compare the effect of lacquer varnish and *rhus* lacquer on the resonant frequency of the solid woods for the violin at each typical mode. So we estimated the acoustical influence of lacquer varnish and traditional *rhus* lacquer as finishing material for these stringed instruments by measuring the resonant frequency at each mode and by comparing the frequency decrement before and after the coating.

2. MATERIALS & METHODS

2. 1. Specimen Preparation

For this study, flitches of European Spruce (M. C: 11.53%) and European maple (M.C: 9.33%) were used in making the main parts of violins, the parts being : the front plate, the bridge, the bass-bar, and the soundpost. For each part ten specimens were made depending on the direction of cutting (R&T) for a total of 40 specimens and were cut out 1㎝ × 2㎝ × 30㎝.

Table 1. Preparation of specimen

Species	Grain	Quantity (pcs)	(Symbol)
European spruce	Edge-grain	10	(SR*1 1~10)
	Flat-grain	10	(ST*2 1~10)
European maple	Edge-grain	10	(MR*3 1~10)
	Flat-grain	10	(MT*4 1~10)

SR*1 : radially cut spruce
ST*2 : tangentially cut spruce
MR*3 : radially cut maple
MT*4 : tangentially cut maple

2. 2. Finishes and Finishing

Specimens of SR, ST, MR and MT, each numbered 1~5, were given three coats of *rhus* lacquer (RL), applied with a brush, and allowed to cure at room temperature. The other specimens, numbered 6~10, were given three coats of lacquer varnish (LV), sprayed on, and allowed to cure room temperature.

2. 3. Vibration measuring apparatus

Measurement of the resonant frequency was performed using the same apparatus as in part 1. (see Fig. 1)

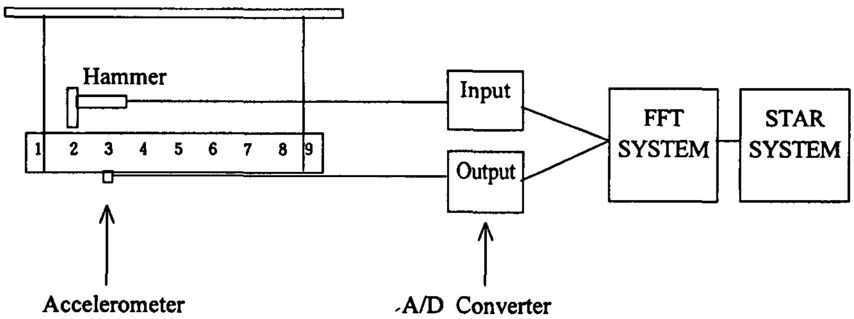


Fig 1. Schematic diagram of vibration modal test.

3. DISCUSSION AND RESULTS

3.1. Fundamental vibration mode and frequency change of the finished specimens

Figure 2 shows the vibration mode of linear model in the finished specimens. This appeared identical to unfinished specimens.

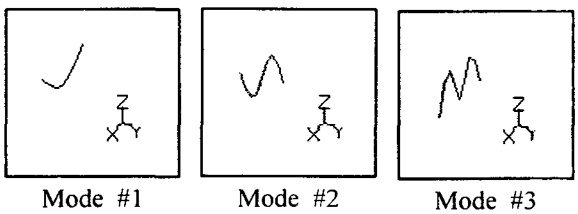
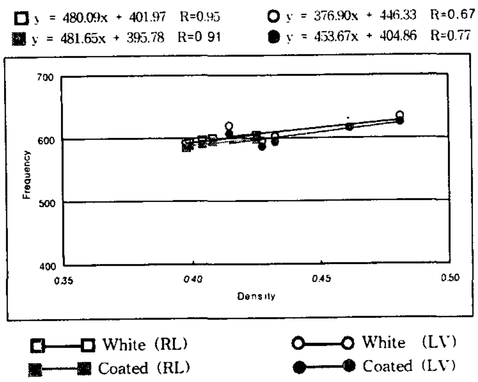


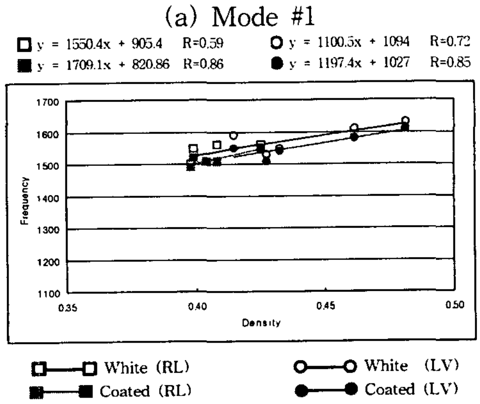
Fig 2. Fundamental vibration mode of coated specimen.

3.2. Frequency change of European spruce depending on coating materials

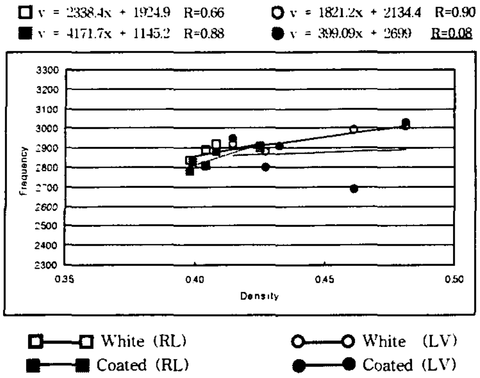
Figure 3 and 4 below show the change of resonant frequency depending on the finishes of European spruce edge-grain and flat-grain specimens. Figure 3 shows that both finishes cause the resonant frequency to decreases because the stiffness of the coatings is lower than that of wood. The different are caused by properties of finishes and absorption of materials. Just as in figure 3, the same decrease of resonant frequency is found in both finishes in figure 4. It is shown that in Mode #3 in figure 3, the frequency of specimen (SR 10) decreases rapidly as the absorption of the finish by this specimen is considerably high.



(a) Mode #1

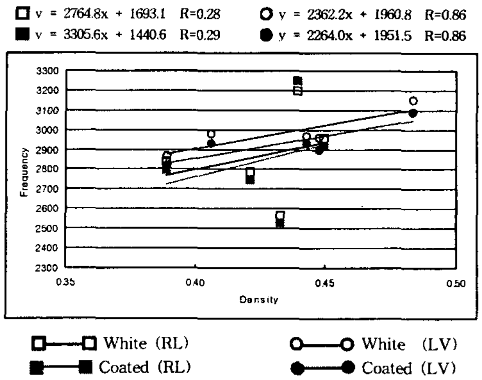


(b) Mode #2



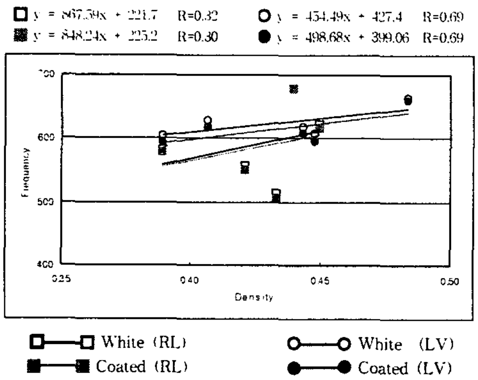
(c) Mode #3

Fig 3. Resonant frequency of edge-grained European spruce.

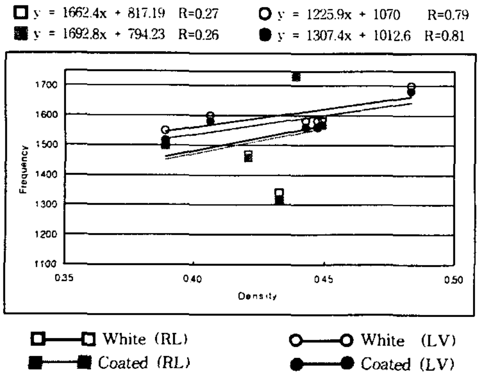


(c) Mode #3

Fig 4. Resonant frequency of flat-grained European spruce.



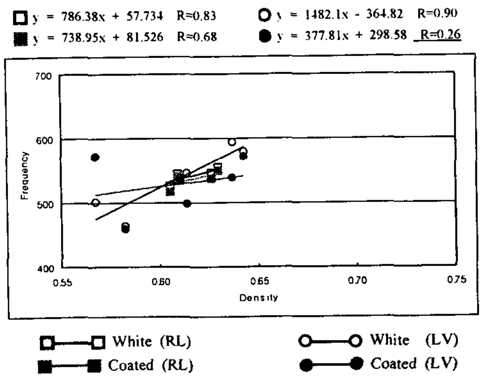
(a) Mode #1



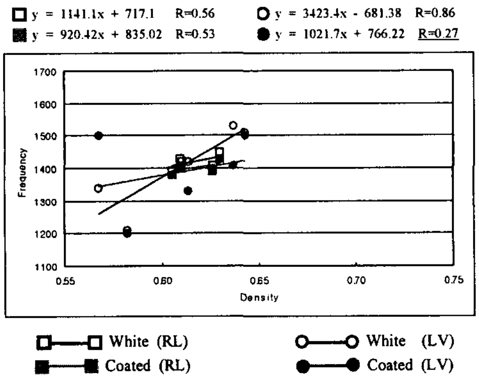
(b) Mode #2

3.3. Frequency change of European maple depending on coating materials

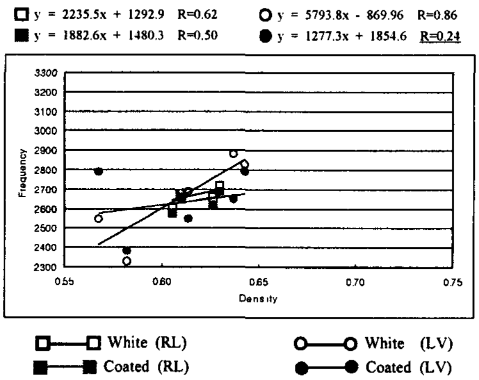
Figure 5 and 6 show the change of resonant frequency depending on the finishes of European maple edge-grain and flat-grain specimens. In maple, the resonant frequency decreases for both finishes. Meanwhile, in the LV specimen of figure 5, as the correlation coefficient decreases before and after finishing maple edge-grain, the frequency decreases depends on the finishing. But in specimen (MR 10), which has the lowest specific gravity, a rapid increase of frequency is shown. It is thought that stiffness increases because low specific gravity materials absorb finishing materials well(rapidly). More detailed analysis is required to find a precise reason for the increase.



(a) Mode #1

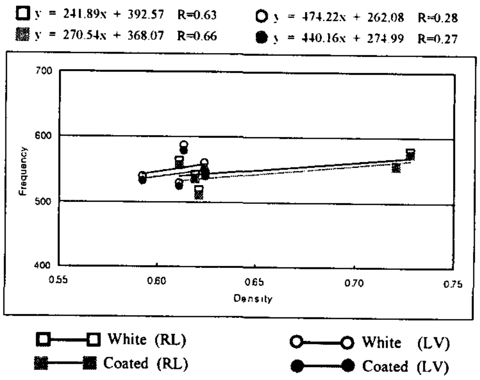


(b) Mode #2

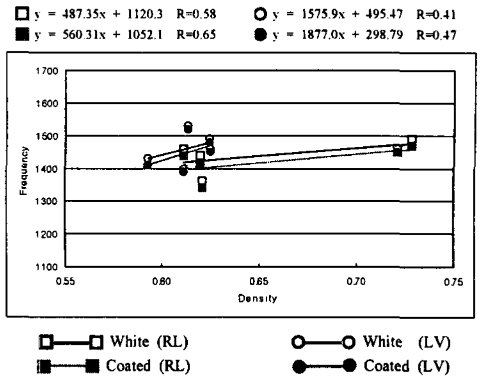


(c) Mode #3

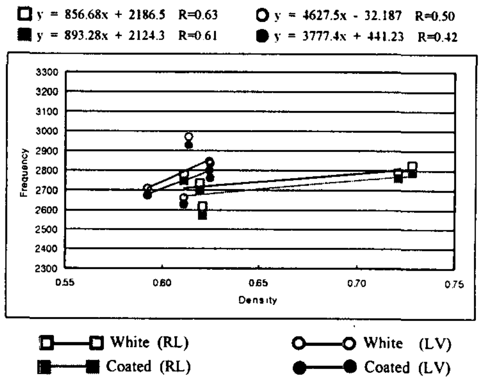
Fig 5. Resonant frequency of edge-grained European maple.



(a) Mode #1



(b) Mode #2

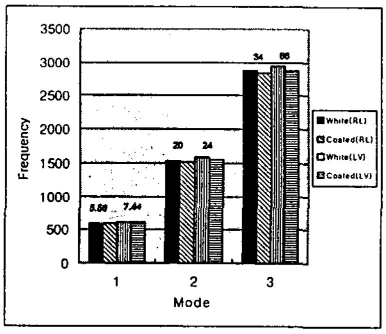


(c) Mode #3

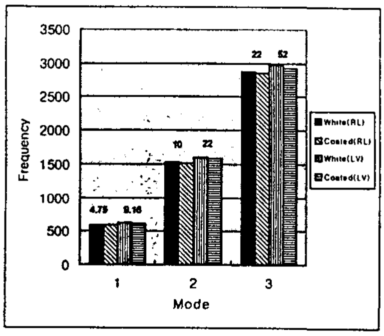
Fig 6. Resonant frequency of flat-grained European maple.

3.4. Resonant Frequencies of European spruce at each mode

Figure 7 shows resonant frequency comparison of each mode of European spruce before and after finishing. It is shown that the frequency of the LV specimen is much lower than that of RL specimen. It is assumed that the low absorbtion of LV or stiffness of LV is lower than that of RL causes the great decrease in total stiffness. So frequency is more decrease. And it is shown that in high modes the decrease grows.



(a) Edge-grained

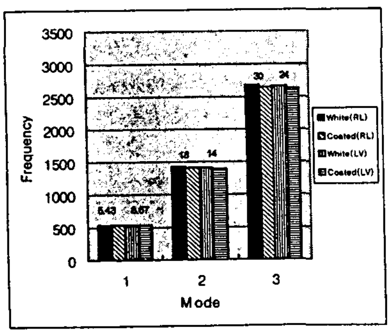


(b) Flat-grained

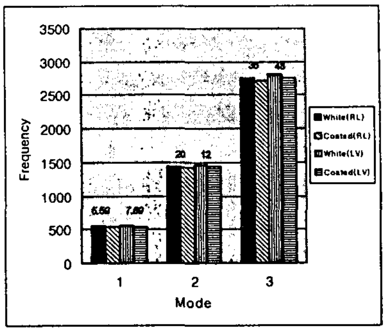
Fig 7. Resonant Frequency of European spruce at each mode.

3.5. Resonant frequencies of European maple at each mode

Figure 8 shows a comparison of each mode of European maple before and after finishing. In a high mode, a larger drop of frequency is shown. However, the frequency drop depending on different finishes shows no regularity.



(a) Edge-grained



(b) Flat-grained

Fig 8. Resonant Frequency of European maple at each mode.

4. CONCLUSION

We measured the resonant frequency using lacquer varnish or *rhus* lacquer as finishing material to analyse the effects of different finishing materials on specimens. The fundamental vibration modes appearing in Part 1 and those after finishing were identical, and the resonant frequency of both wood species after finishing decreased independent of the kind of finish. It is assumed this was because of the low stiffness of the finish. In spruce, it was shown that as modes increase, the decreased of frequency was greater, and the frequency decreased from *rhus* lacquer was less than that of lacquer varnish. On the contrary, as modes increased, the decrease of frequency also was greater in maple, however, the frequency difference of frequency between *rhus* lacquer and lacquer varnish showed no regularity.

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