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Acoustical evaluation of differences in Sanshin's tone depending on shapes of *SAO*

Kojiro NISHIMIYA[1]; Mao TOKUDA[1];Yuki YOKOTA[1], Hideo CHO[1]

[(1)] Aoyama Gakuin University, Japan, nishimiya@me.aoyama.ac.jp

Abstract

Sanshin is an OKINAWA's traditional musical string instrument. Generally, "sound board", "bridge", and "string" are the main factors on the string instrument's tone from the acoustical points of view. Nevertheless, about Sanshin, the players and the craftsman have thought that *Sao* (Neck) has been the most important. Sanshin has many types of *Sao* and there have many arguments of the relationship between "*Sao*" and "Tone (Timbre)". However, the sound mechanism is still not clarified. Therefore, the purpose of this research is to elucidate the sound mechanism of Sanshin which include the influence of *Sao*. We measured the Sanshin's tone using different types of *SAO* with the same body, string, and bridge. As a result, we found the several differences in the tones. Especially the differences were confirmed in the overtone distributions and the attenuation rates. For the understanding of these behaviors, we focused about the change of the thickness of *SAO*, and the mass loading of the head of *SAO*. By the cutting process of one wood-Sanshin, we found that the thickness of *SAO* influences the overtone distributions and the mass loading influences the attenuation at the ringing tone.

Keywords: Sanshin, Okinawa, *Sao*, string instruments, coupled vibrations, eigen frequency, bending stiffness

1 INTRODUCTION

Sanshin is an Okinawa's traditional string musical instruments and it has been always invaluable role for Okinawans. Sanshin is used to play in the various events and ceremonies. Also, Sanshin has a role not only as an instrument but also as a traditional craft. Therefore, it is also required the beauty of the shape. Sanshin has many types of *Sao* (Neck), although "Shamisen", which is the similar instruments as Sanshin in Japan, doesn't have such many types. This is one of the unique characteristics of Sanshin. Furthermore, the players and the craftsman of Sanshin have thought that the *Sao* has been the most important and there have many consideration and research results about *Sao* [1]. Also, there have many arguments of the relationship between "*Sao*" and "Tone (Timbre)". However, the sound mechanism of Sanshin is still not clarified from the acoustical points of view. Although some attempts for the sound analysis of Sanshin have been made [2,3,4], the detailed mechanism is still not clarified and also the different types of *Sao* are not evaluated. Therefore, we aim to elucidate the sound mechanism which include the influence of *Sao*. The different types of *Sao* with the same string, bridge, and body, were evaluated. Also, the influence of the thickness of *Sao* and the weight of top of *Sao* (which is called "*Ten*") by the cutting process using one wood sanshin were evaluated.

2 Characteristics of Sanshin

Sanshin mainly consists of "*Sao* (Neck)", "String", "Body", and "*Koma* (Bridge)". Detailed structure of Sanshin is shown in Figure 1. "*Ten*" is a top of *Sao* and the shape of *Ten* is various with different types of *Sao*, and *Ten* becomes the mass loading to the *Sao* in the vibration condition. A part of *Sao* is called as "*Shin*" and it is inserted in the body. Three strings are fixed by the edge of *Shin* (*Itokake*) and *Itogra*. Currently the strings made by the nylon and Tetron are generally used, although the silk strings were extensively used before.

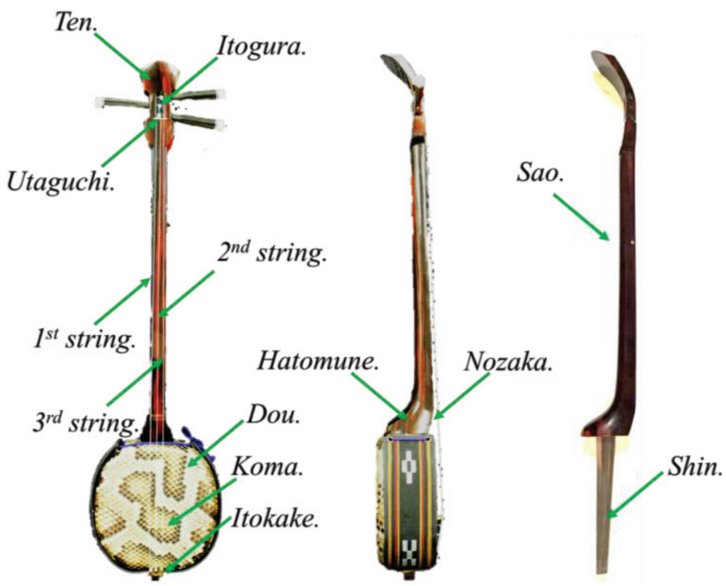


Figure 1. Structure of Sanshin

3 Measurement Method

In the acoustical measurement of the music instruments, the repeatability is most important. Sanshin is played by picking Bachi (pick) and the picking angle and the speed are different with the people and also for each music. The auto picking system was manufactured for the improvement of the repeatability [5]. The structure of the auto picking system is shown in Figure 2. Bach is rotated by the stepping motor and is controlled by the motor driver which is programed by the Raspberry Pi. Then the picking speed is controlled and also the position of Bach is fixed by the frame. The sides of the body of Sanshin is fixed by the pins and also the *Sao* is put on the formed polystyrene for not preventing the vibration of the instrument.

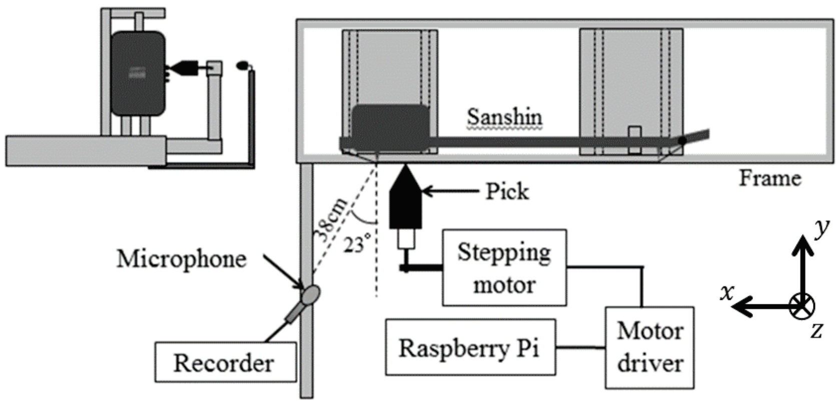
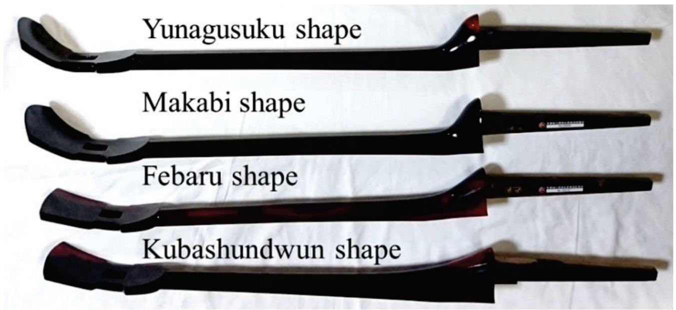


Figure 2. Auto picking system for Sanshin

4 Evaluation with different types of *Sao*

Four types of *Sao* were measured for this research. Figure 3 shows the photo of the *Sao*. The names of types are "*Yunagusuku*", "*Makabe*", "*Febaru*", and "*Kubashundwun*", respectively. The materials of woods are all same "*Kokutan* (ebony)". The same "string", "bridge", "body" and "*Koma*" are used for the measurement and the *Sao* is only changed by each measurement. The microphone is set above 30 cm from the *Koma*. The acquisition waveforms of sound are shown in Figure 4. Horizontal axis is time [s] and vertical axis is amplitude. Is is known that the waveform of Sanshin has double attenuation. They are the attenuation at the attack tone (immediately after the picking) and the attenuation at the ringing tone. The frequency spectra at the both tone were evaluated and the peak amplitude of each overtone was extracted. The overtone distributions are shown in Figure 5. The attack tone is until 0.05s after the picking and the ringing tone is after 0.05s in this analysis. From this result, it was found that the ringing tone have totally different overtone distributions with different *Sao*s, on the other hand, the attack tones have two trends of the overtone distributions. "*Makabe*" and "*Febaru*" are similar distributions and the maximum peak amplitude were 6^{th} overtone, and "*Yunagusuku*" and "*Kubashundwun*" are the similar distributions and the maximum peak amplitude were 7th overtone. The similarity of "*Yunagusuku*" and "*Kubashundwun*" from the geometrical points of view, are the thickness of *Sao*. Comparing to "*Makabe*" and "*Febaru*", the thicknesses are both thicker. Therefore, it has a possibility that the thickness of *Sao* affects to the overtone distributions at the attack tone.



(a) Side View

(b) Top View

Figure 3 Photo of different types of *Sao*

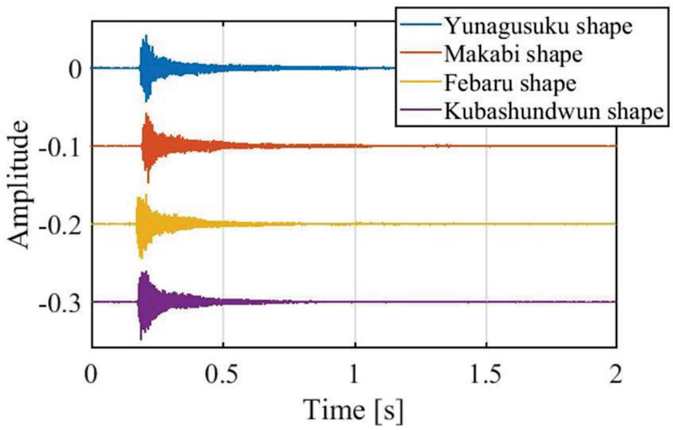


Figure 4 Time waveforms of different types of *Sao*

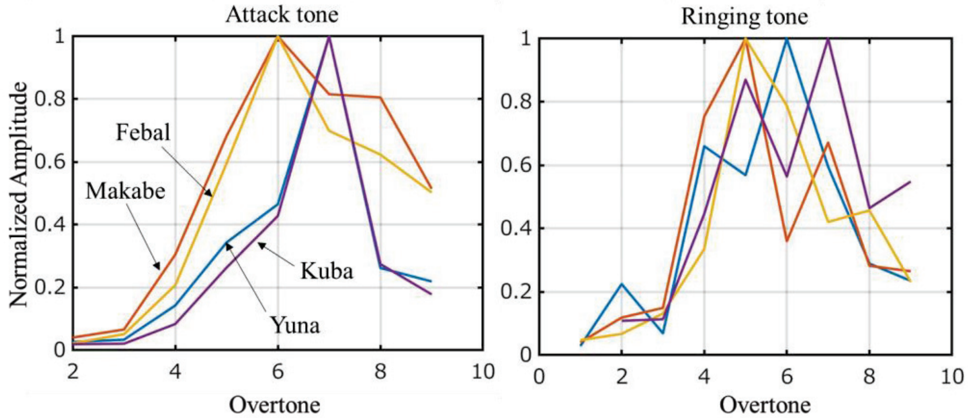
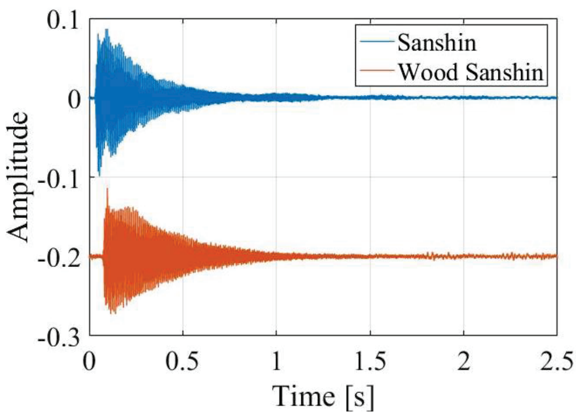


Figure 5 Overtone distributions with different types of *Sao*

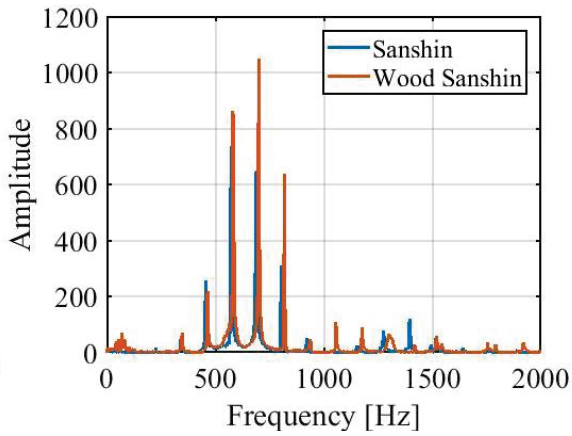
5 Wood Sanshin with cutting process

From the results of acoustical evaluation with different *Sao*s, the influences of *Sao* were confirmed. However, it is difficult to conclude the cause of the influence, because there are many different parameters among each *Sao*. We used the same wood materials, but the actual wood parameters should be different due to the gnarl and the anisotropy of the woods, etc. Also, the thickness of *Sao* is different in each position and each type. Therefore, we cannot compare the thickness of *Sao* with different type simply. Therefore, we conducted the acoustical evaluation using one wood Sanshin with cutting process. Wood Sanshin is one of the Sanshin for the practice and the photo is shown in Figure 6. We can simply evaluate the difference of the thickness of *Sao* by cutting process. First, the characteristics of wood Sanshin was compared with the normal Sanshin (*Yunagusuku* type). The results of time waveform and the frequency spectra are shown in Figure 7. The waveform of wood Sanshin looks slightly low attenuation than normal Sanshin, and the frequency spectra are similar from Fig. 7 (b). Also, the comparison of the overtone distribution is shown in Fig. 7(c). Generally, they are similar distributions, although the maximum peak amplitude of normal Sanshin was 5^{th} and it of wood Sanshin was 6^{th}. Also, the higher modes around 12^{th} overtone of normal Sanshin have several amplitudes, however, the modes of wood Sanshin have few amplitudes.

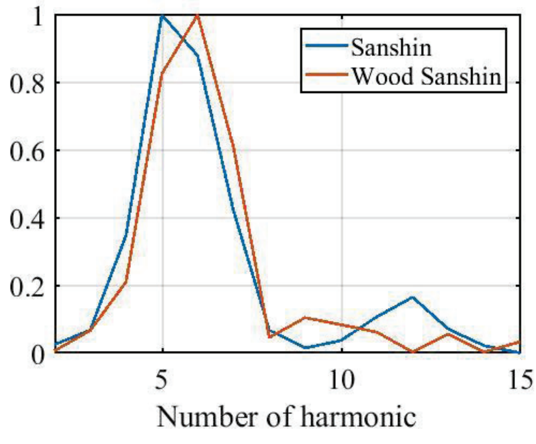
Figure 6 Photo of normal Sanshin and wood Sanshin



(a) Time Waveform



(b) Frequency Spectra



(c) Overtone distributions

Figure 7 Acoustical comparison between normal Sanshin and wood Sanshin

Sao was cut to the thickness direction as shown in Figure 8. Original thickness of *Sao* was 23 mm and 10 mm was cut. For the comparison of the eigen frequencies of *Sao* before and after cutting process, the hitting test was conducted. The acceleration pickup was attached at the "*Utaguchi*" and the center of *Sao* was hit by the impact hammer. The results are shown in Figure 9 (a). Horizontal axis is frequency [Hz] and vertical axis is the amplitude. The eigen frequencies of thinner *Sao* by cutting process were generally lower than the original *Sao*. The acoustical evaluation before and after the cutting process was also conducted. Time waveforms of the sound and the overtone distributions are shown in Figure 9 (b) and (c). The time waveforms were similar amplitude and attenuation ratio, however, the overtone distributions were slightly different. The maximum peak amplitude of the original wood Sanshin was 6th overtone, although the maximum peak amplitude of the thinner *Sao* was 5th overtone.

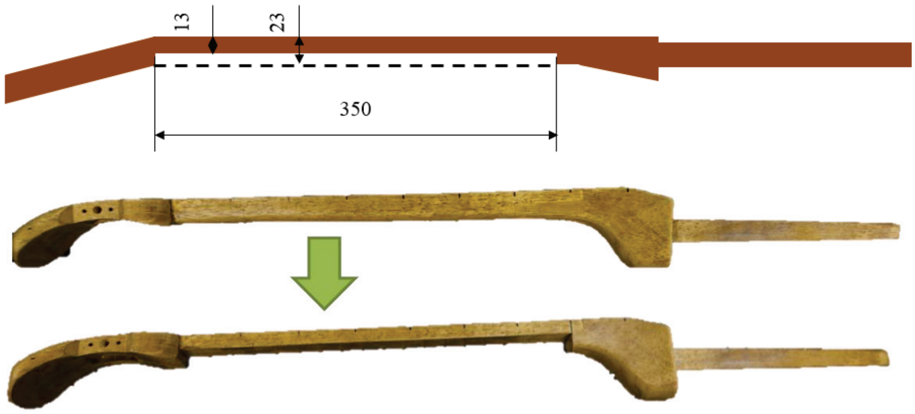
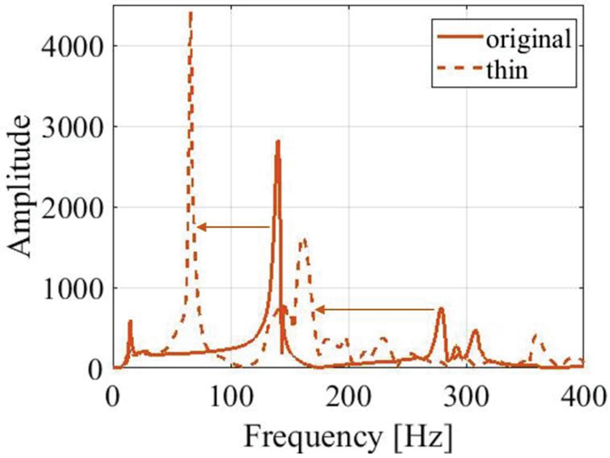
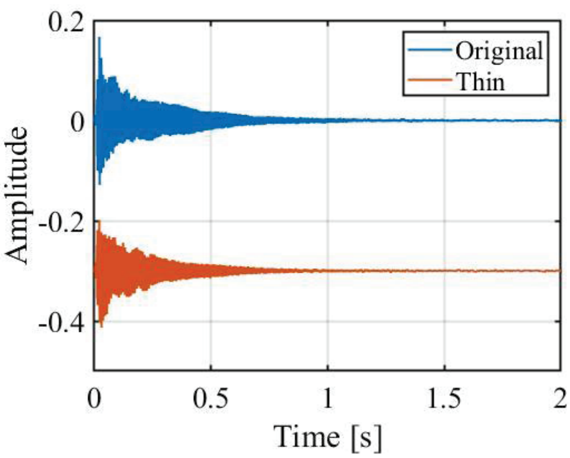
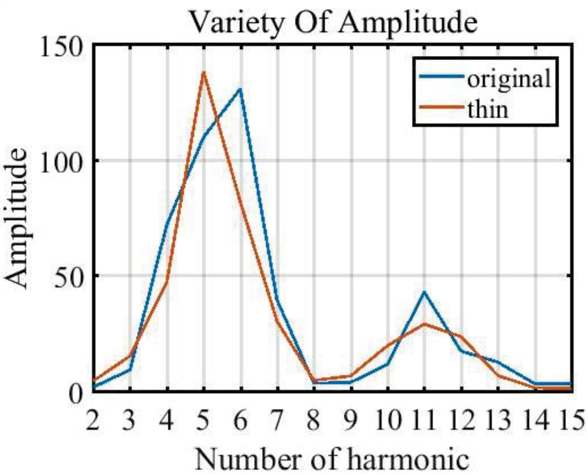


Figure 8 Cutting process of wood Sanshin for the reduction of thickness of *Sao*



(a) Frequency spectrum of vibration of *Sao*



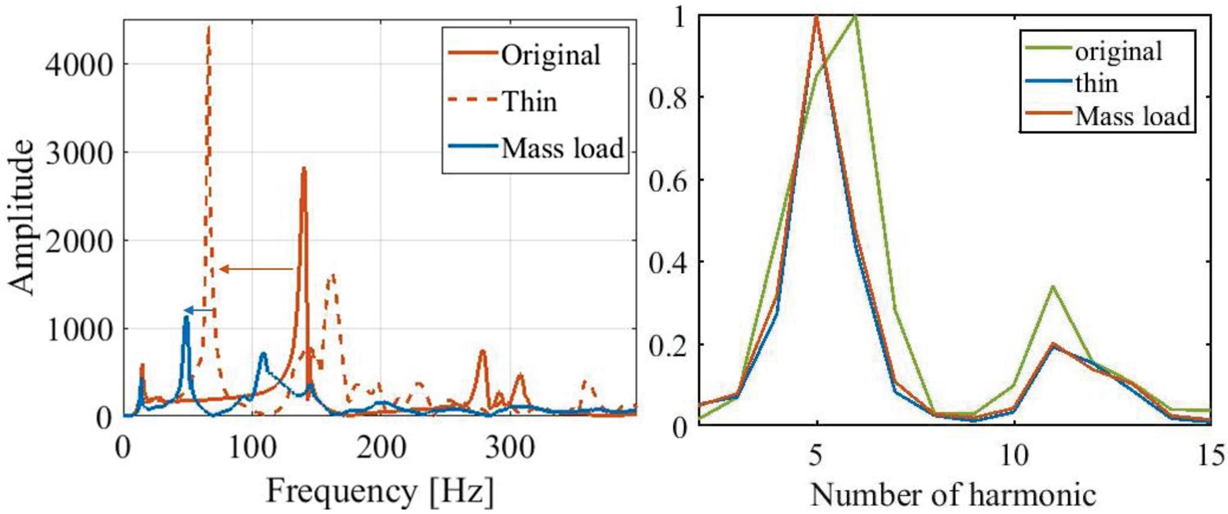


(b) Time waveform of sound (c) Overtone distributions of sound

Figure 9 Acoustical comparison before and after the cutting process of the thickness

The change of the overtone distributions was generated by the difference of the thickness of *Sao*. In other words, the change was generated by the change of "eigen frequency" and "bending stiffness" of *Sao*. In order to understand the dominant factor of the change between "eigen frequency" and "bending stiffness", we conducted the additional test. The clay was added on *Sao* as a mass loading as shown in Figure 10. When the mass loading is added on a material, it is considered that the eigen frequencies decrease but the bending stiffness does not change. The results of eigen frequency by the hitting test is shown in Figure 11 (a). The eigen frequency of original *Sao*, thinner *Sao*, and thinner *Sao* with mass loading are shown. The eigen frequency of *Sao* with mass loading decreased from *Sao* without mass loading. The results of the acoustical test acquired by the microphone is shown in Figure 11 (b). The overtone of maximum peak amplitude of thinner *Sao* decreased from the original *Sao*, but the overtone distribution of the thinner *Sao* with mass loading did not change from the thinner *Sao* without mass loading at all. This means that the change of the overtone distributions due to the decrease of the thickness of *Sao* was generated by the "bending stiffness" rather than "eigen frequency".

Figure 10 additional mass loading to *Sao* by clay



(a) Frequency Spectra (b) Overtone distributions

Figure 11 Acoustical comparison among original *Sao*, thinner *Sao* and thinner *Sao* with mass loading

Finally, the influence of the "*Ten* (top of *Sao*)" was evaluated. The shape and the weight of "*Ten*" differ substantially among the types of *Sao*. Therefore, it is considered that "*Ten*" becomes the mass loading to *Sao*. The weight of *Ten* decreased by the cutting process as shown in Figure 12, and the eigen frequency and the acoustical evaluation were conducted. Figure 13 and Figure 14 show the results of the eigen frequency by the hitting test and the acoustical evaluation by the microphone, respectively. The eigen frequency of *Sao* with the cutting *Ten* increased because of the less mass loading. From the results of time waveforms in Figure 14 (a), the waveform of the *Sao* with cutting *Ten* attenuated soon after the picking. The envelope of the time waveforms with logarithmic scale is shown in Figure 14 (b). The attenuation of the waveform of *Sao* with cutting *Ten* was larger than that of *Sao* without cutting *Ten*. It has a possibility that the large attenuation is caused by the decrease of the inertia due to the less mass loading. The overtone distributions at the ringing tone had large difference with the different types of *Sao* in the section 4, therefore, the existence of *Ten* could affect to the attenuation, especially at the ringing tone. Also, this difference of the attenuation could affect to the overtone distributions at the ringing tone.

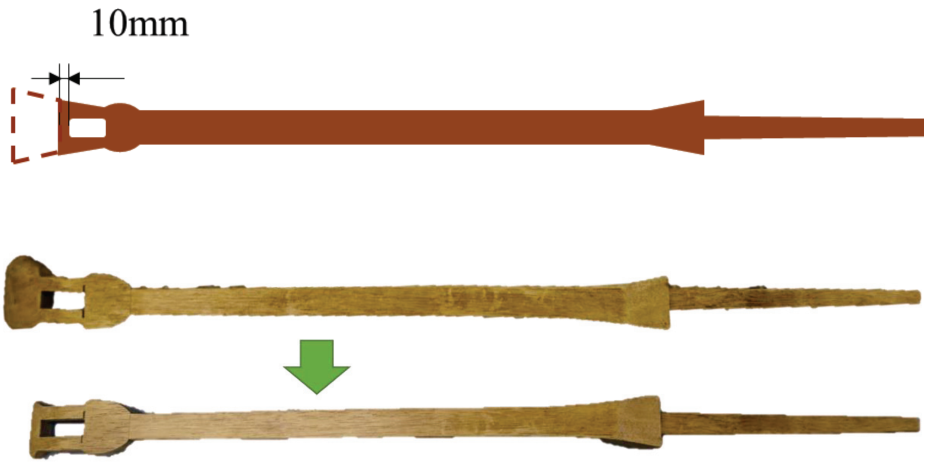


Figure 12 Cutting process of wood Sanshin for the reduction of weight of *Ten*

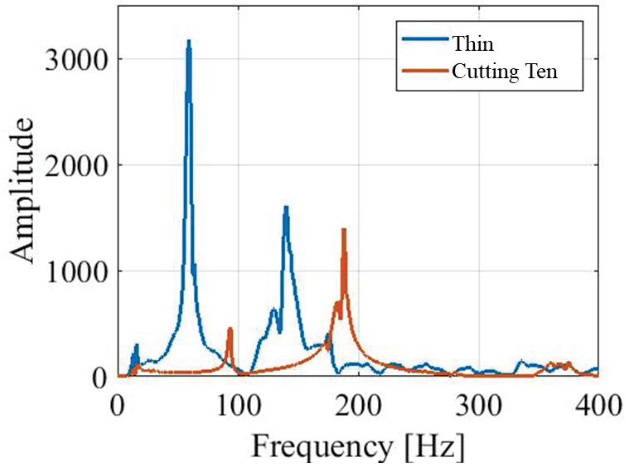
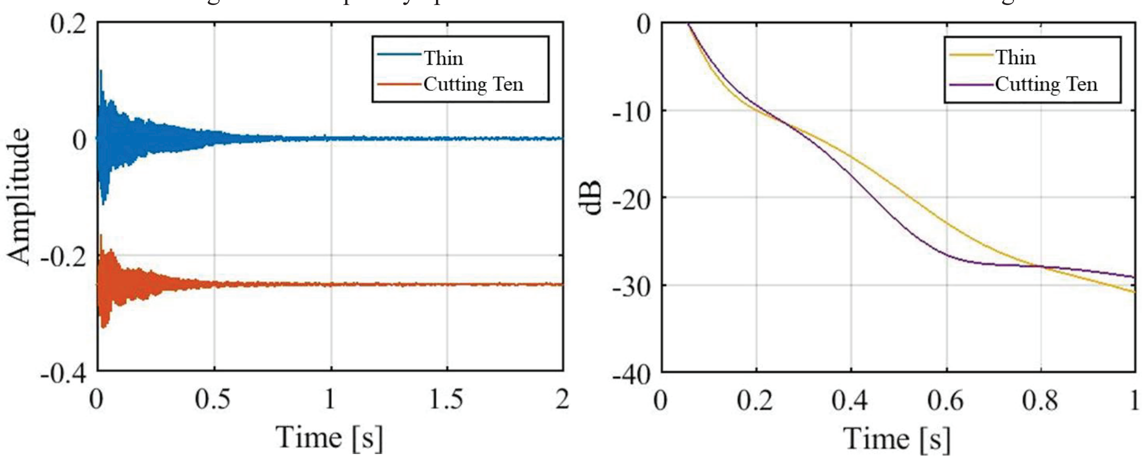


Figure 13 Frequency spectrum of thinner *Sao* and thinner *Sao* with cutting *Ten*



(a) Time waveforms (b) At*Ten*uation rate

Figure 14 Acoustical Comparison between thinner *Sao* and thinner *Sao* with cutting *Ten*

6 CONCLUSIONS

Acoustical evaluation of Sanshin in order to understand the influence of *Sao* were conducted. Using same "string", "body", and "*Koma* (bridge)", the different types of *Sao* were characterized. Dividing attack tone and ringing tone, it was found the differences in the overtone distributions among each *Sao*. In the attack tone, the overtone distributions had a trend which was depending on the thickness of *Sao*, on the other hand, in the ringing tone, the overtone distributions were substantially different with different types of *Sao*. For more detailed analysis, the acoustical evaluation with wood Sanshin by the cutting process was conducted. The thickness of

Sao and the weight of *Ten* were changed by the cutting process. As a result, we found two considerations. First, the change of the bending stiffness due to the decrease of the thickness could affect to the overtone distributions. Second, the change of the inertia due to the change of the mass loading at *Ten* could affect to the attenuation and also it could affect to the overtone distributions.

These results are still not enough as a quantitative evaluation, and so further measurements and analysis are going to be conducted in the future. Especially the coupled vibration among “string”, “body”, “bridge” and “*Sao*” will be analyzed.

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