# Acoustical Characteristics of the Gayageum: A Twelve-stringed Korean Traditional Musical Instrument.

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**ABSTRACT** The Gayageum is one of the most popular traditional string instruments of Korea. It consists of wooden body made of paulownia tree, twelve silk thread strings, and twelve wooden bridges that support each string. The player plucks strings with right hand and controls the string's tension for Nong-hyun (which is similar to vibrato technique) with left hand. In this paper, acoustical characteristics of Gayageum are discussed based on various measurement results.

## 0. INTRODUCTION

The Gayageum is one of the representative Korean traditional string instruments. It is a plucked musical instrument that has its origin in ancient China. It is said that the Gayageum was made by King Kasil in the Gaya Kingdom around the 6th century and then it has been improved by Wu Ruk in the time of King Jinhung in the Silla dynasty. However, there is evidence that its use must have traced back to much earlier time than the time of the Silla dynasty, as shown in the recent archeological excavations in the Kwangsan areas in Jeolla-namdo Province, where

some fragments of a Gayageum used in around B.C. 1st century were found.

We can find many Gayageum-like musical instruments in Asia and we call them generally as Geum family. The Zheng (China) and the Koto (Japan) also belong to this family.

Nowadays, the Gayageum is employed in two different types of music. The one is Jeong-ak, which was court music in Korea. The other is Sok-ak, which was folk music. The Gayageum used in Jeong-ak is called Pungryu-Gayageum. It is the original form of the Gayageum. Sanjo-Gayageum, which is used in Sok-ak, has smaller size and narrower gap between the two adjacent strings than the former to suits the music with fast tempo such as Sanjo. These days Sanjo-Gayageum is widely used and preferred. In this paper, Sanjo-Gayageum is measured and presented. (Fig. 1)

Recently, In order to play the modern music, strings are added into a Gayageum by making its body much wider, known as "21 strings Gayageum" so that its range is widen. The Gayageum is used not only in ensemble but also in solo.

The Gayageum is 160 centimeters in length, 26 centimeters in width, and 5 centimeters in height, which is made of paulownia wood. The top plate has a gently curved shape, and the bottom plate has a flat shape with three holes on it. (Fig. 2) The Pungryu-Gayageum does not have bottom plate. The Anjok (twelve movable bridges) supports twelve strings that are made of twisted silk threads with different gauge. The tension of each string is about 3~5Kg (30~50N). Compared with violin family, it is much low value. It makes easy to play Nong-hyun (which is similar to vibrato technique), but due to its low tension, the sound level of the Gayageum is relatively small. They are tuned to 75 ~432 ($E_2$b~$B_4$b) (Table 4).

The playing technique of the Gayageum is as follows. The left-hand is used for pressing the strings and its finger movements can be made various types of movements such as shaking, bending, vibrating the strings. The right hand is used for plucking the strings. The Nong-hyun technique of the Gayageum is very slow (0.3~0.4 seconds in period) and has wide pitch variation (80~130 cents).

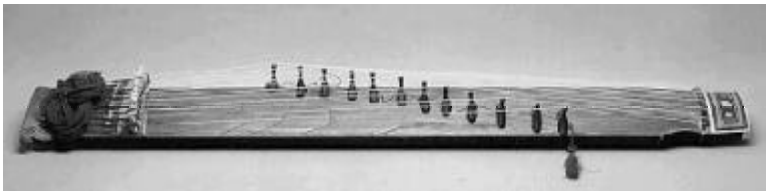

Fig. . Sanjo-Gayageum

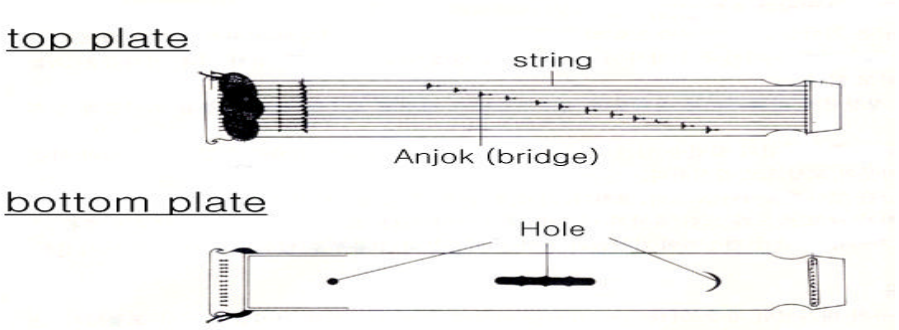


Fig. . Sanjo-Gayageum

Generally, a string instruments can be regarded as the combination of string, bridge, and body. The timber of a string instruments is determined by the acoustical characteristics of these parts and of the auditory space which the instruments is played. According to past research works, the body plays a most important role in characterize the timber. Much work has been done on violin family, but very little on these traditional musical instruments.

Including the Anjok, the string and the body of the Gayageum are coupled at many points. This makes it difficult to obtain the body's transfer function. So we set up each position of Anjok for measurement points and measured impulse responses. In this paper, the result of center position (6th Anjok) is presented

## 1. EXPERIMENT

Measurement equipments are as follows.

| Equipment | Type |
|---|---|
| Microphone | B&K Type 4011 |
| Microphone preamp | Tascam DA-P1 |
| Analysis software | Matlab ver5.3, Cool Edit Pro |

Table 1. Measurement equipments

The body, which radiates sound of the instruments, is one of the most important part of the Gayageum. To obtain acoustical characteristics of the body, measurements of impulse responses must be done first. Then, using the Chladni (Chladni, Ernst Florens Friedrich, 1756~1827) pattern method, dominant resonance modes of the body can be obtained.

The measured samples are as follows.

1) A top plate of the Gayageum (top plate only)

: We first examine the vibrational characteristic of the top plate and then compare with that of the complete Gayageum.

2) A complete Gayageum

: A work of the most celebrated craftsman in Korea.

## 2. RESULTS

First, we obtain a 3D-spectrogram of the plucked string to observe the timber and spectral transition of the Gayageum according to time. It shows that the Gayageum bears less and rapidly disappearing harmonics compared to violin family. For this reason, the timber of the Gayageum is dark but elegant.

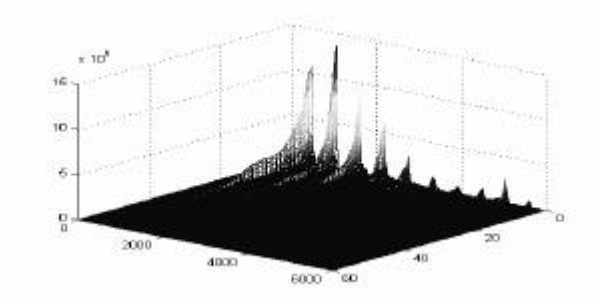

Fig. . 3D-spectrogram of the plucked string

Impulse responses and dominant resonant peaks of each sample are as follows. The gray cell in table 2 and 3 indicates the resonance frequency of the Chladni pattern.

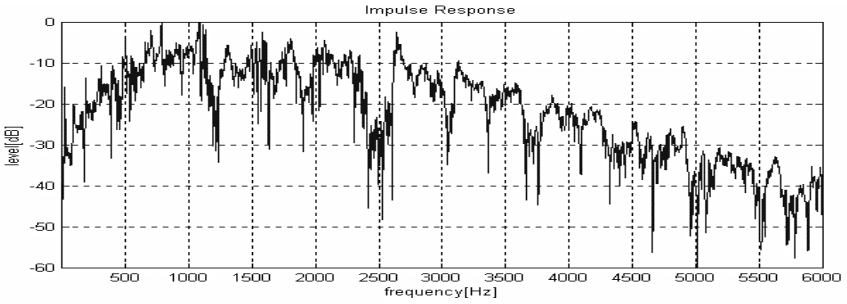


Fig. . Impulse response of the top plate only

| 0~100 [Hz] | 100~200 [Hz] | 200~300 [Hz] | 300~400 [Hz] | 400~500 [Hz] | 500~600 [Hz] |
|---|---|---|---|---|---|
| 95 | 190 | 281 | 398 | 479 | 505 |
| 50 | 168 | 252 | 311 | 412 | 551 |
| 71 | 153 | 224 | 361 | 428 | |
| | 112 | 267 | 340 | 444 | |
| | 136 | 239 | 329 | 467 | |
| | 123 | 208 | 377 | | |

Table 2. Major resonant peaks of the top plate only

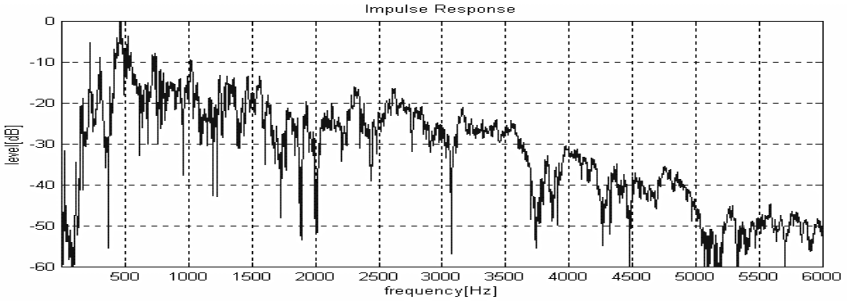


Fig. . Impulse response of the complete body

| 0~100 [Hz] | 100~200 [Hz] | 200~300 [Hz] | 300~400 [Hz] | 400~500 [Hz] | 500~600 [Hz] |
|---|---|---|---|---|---|
| 765 | 164 | 224 | 300 | 457 | 521 |
| 80 | 147 | 240 | 312 | 437 | 542 |
| 98 | 185 | 271 | 379 | 483 | 557 |
| | 113 | 252 | 392 | 413 | |
| | 137 | 205 | 327 | 499 | |
| | 125 | | 361 | | |

Table 3. Major resonant peaks of the complete body

The violin family has huge number of peaks and dips on their frequency response. But, on the contrary, the impulse response of the Gayageum shows an even response in frequency domain. Comparing the results from the top plate with that of the complete body, there is a little difference in high frequency region. But in low frequency region below 500Hz, the result from the complete body shows much bigger response. The reason is that in the case of the complete body, as the boundary of the top plate is fixed, there is increase in its stiffness and this brings increased efficiency of low frequency radiation. Moreover, the body with small hales acts as a Helmholtz resonator for low frequency.

To get Chladni patterns of the samples, we spread sand on them and excite with sine sweep signal. Table 4 shows pitches of tuned strings and resonance frequencies obtained from Chladni pattern method. These resonance frequencies appear nearby the pitches of each string. It is a general phenomenon for the most of string instruments. This makes the body more efficient for sound radiation.

| string No. | pitch [Hz] - key | top plate only [Hz] | complete body [Hz] |
|---|---|---|---|
| 1 | 75 - $E_2b$ | 84 | 81 |
| 2 | 100 - $A_2b$ | 101 | 103 |
| 3 | 109 - $B_2b$ | 115 | 120 |
| 4 | 150 - $E_3b$ | 142 | 140 |
| 5 | 159 - $F_3$ | 160 | 150 |
| 6 | 201 - $A_3b$ | | |
| 7 | 214 - $B_3b$ | | 220 |
| 8 | 244 - $C_4$ | 243/254 | |
| 9 | 298 - $E_4b$ | 280 | 274 |
| 10 | 319 - $F_4$ | 320/363 | 348 |
| 11 | 395 - $A_4b$ | 405 | 360/390/400/410 |
| 12 | 432 - $B_4b$ | 430 | |

Table 4. Tuned pitch of each string vs. resonance frequency of the body

Here are some Chladni patterns we obtained.

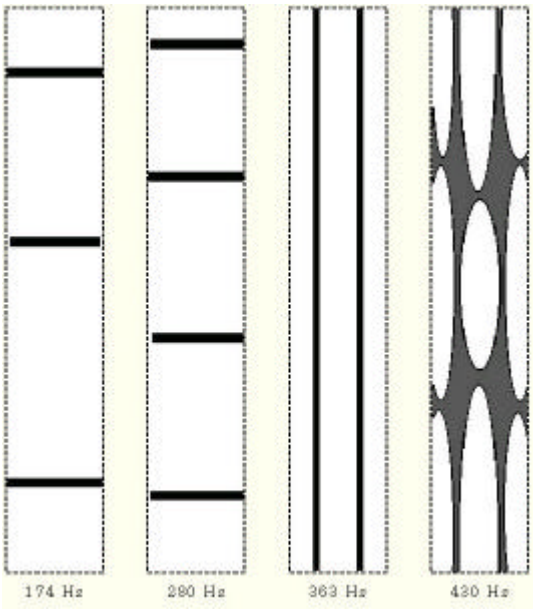


Fig. . Chladni patterns of the top plate

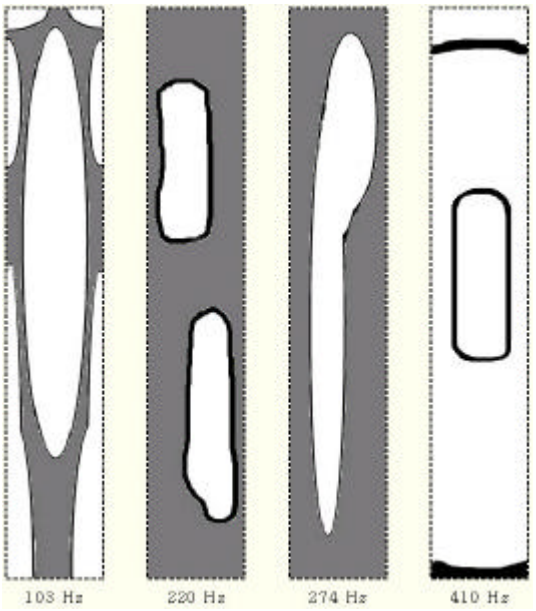


Fig. . Chladni patterns of the complete body

**3. CONCLUSIONS AND FUTURE STUDIES.**

In this paper, a study on the acoustical characteristics of the Gayageum is presented. Compared to violin family, the Gayageum has lower tension and bears fewer harmonic. And it has low musical range for its size. These features make the Gayageum have dark but elegant tone.

Researches on air cavity resonance of the body, the acoustical characteristics of the string, and studies on the interactions of each component will be our future works.

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