

## Sound Quality Improvement Using Digital Filter in Carbon Body Renovate Haegeum

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**Abstract:** Since, 2000, the trend of Korean traditional music and Korean traditional musical instruments is consumption of musical instruments and music is becoming more popular among the public. And there is a growing interest in traditional music and more specific curiosity about traditional musical instruments. However, the systematic research on Korean traditional musical instrument production has not yet achieved high performance, furthermore, the production of musical instruments is not out of the limit of craft technology. Because it is a 'traditional musical instrument', it is produced in a traditional way, mainly using wood which is a material transferred from the past. Although, it may achieve the goal of preserving tradition and conveying the sound of tradition, it is difficult to create a good instrument that satisfies popular popularity and demand for traditional instruments without changing materials and method. Wood is easy to obtain from nature has good handling characteristics but is not suitable for mass production. In addition, traditional instruments are difficult to learn and play in terms of how to handle them and how to manage them. Traditional Korean musical instruments haegum has been produced by musical instrument master makers who have maintained the classical method of using traditional and wood materials. For that reason, the amount of instruments supplied is so, small that it does not meet the demand to learn and play haegum. And even if you try to play the traditional haegum for a hobby or education, it is hard to play and hard to manage compared to the effort of the person to learn. In this study, we compare the sound of traditional haegum and carbon body renovate haegum which are produced by master and 3D printing each. The improvement of the renovate haegum was confirmed and the sound source was analyzed. We also introduce how to enhance the sound quality by adding a digital filter.

**Key words:** Musical instrument, haegum, hybrid haegum, acoustic analysis, improvement, 3D printing

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### INTRODUCTION

String instrument accounts for more than half of the traditional instruments of the world (Bae, 2013). Musical instruments have various characteristics which can be classified into strings, wind instruments and percussion instruments by their appearance and performance (Bae, 2013; Park and Bae, 2017a, b). It distinguishes between how to generate, to resonate, to propagate and how to hear sound (Park and Bae, 2017a, b). Various materials are used to make folk instruments such as wood, leather, silk and metal. Among them, timber is easier to obtain in nature than other materials and has become an important material for making various musical instruments in easy processing features (Bok-Kon, 2010). However, this wood is easy to handle but it is consistently good quality and not suitable for mass production. Especially in the case of Korean folk instruments, the production of musical instruments is the same as the production of handicrafts (Bok-Kon, 2010; Choi, 2008). Therefore, it is produced only by skilled artisans and the production methods and

processes are transferred in apprenticeship (Choi, 2008; Yoon-Joo, 2015). And even if there is a formal recipe for making or distributing instruments, the recipe and method differ depending on the shape and the characteristics of the wood which is the material and the permissible errors in the manufacturing process make the instrument of the same quality as the products made mechanically at the factory it is difficult (Yoon-Joo, 2015; Hwan, 2014). Moreover, assembling and assembling parts of the same dimensions unconditionally have similar appearance, by solving this difficulty of mass production (Hwan, 2014; Suok-Kim, 2014). However, it is not easy to manage the sound sources generated from the musical instruments to be kept the same and even. The same is true of traditional Korean musical instruments 'Haegeum' (Bae, 2013; Park and Bae, 2017a, b; Bok-Kon, 2010; Choi, 2008; Yoon-Joo, 2015; Hwan, 2014; Suok-Kim, 2014).

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interest in traditional music and more specific curiosity about traditional musical instruments. However, the systematic research on Korean traditional musical instrument production has not yet achieved high performance, furthermore, the production of musical instruments is not out of the limit of craft technology (Yoon-Joo, 2015; Hwan, 2014). Because it is a 'traditional musical instrument', it is produced in a traditional way, mainly using wood which is a material transferred from the past. Although, it may achieve the goal of preserving tradition and conveying the sound of tradition, it is difficult to create a good instrument that satisfies popular popularity and demand for traditional instruments without changing materials (Choi, 2008). To overcome these limitations, Korea has been producing improved traditional musical instruments through the improvement of traditional musical instruments, since, the 1980's (Yoon-Joo, 2015). However in such cases, it is generally not possible to inherit the quality of the sound of the traditional musical instrument, it was a common problem that if the acoustic side of a musical instrument was reinforced, it would return to the way of producing a traditional musical instrument (Hwan, 2014). And haegeum which is manufactured in a traditional way has different shapes and sizes of instruments depending on the production method (production craftsmen) and the condition of materials (Suok-Kim, 2014). In addition, there is a characteristic of each musical instrument and it takes a lot of time until the player can adapt that and play smoothly (Park and Bae, 2017a, b). Also, traditional instruments are harder than improved instruments to play, such as until tuning, playing good sound, keep clear sound for those musical instruments learner. And compared to the effort to learn, the performance result is harder than you think (Park and Bae, 2017a, b).

As mentioned earlier, there is a growing demand for the performance and education of traditional stringed instruments (Bok-Kon, 2010). As a result, there is an increasing tendency to play and have haegeum, also. In elementary school, there is an attempt to learn haegeum performance and to play a concert in after school music class (Park and Bae, 2017a, b; Oh, 2009). However, traditional haegeum is difficult to supply and educate because of the limitations of the manufacturing process (Bae, 2013). Traditional haegeum which is made by instrument craftsmen is often expensive for musicians who wants to have individual (Yoon-Joo, 2015; Suok-Kim, 2014). Furthermore, the amount of haegeum production is small in school, they use low-cost instruments produced in China (Park and Bae, 2017a, b). However, it is difficult to educate the Chinese cheap haegeum because it takes a lot of time to prepare, tune and manage the music, to regenerate the sound in different musical instruments and

to arrange for the performance (Oh, 2009). It is difficult to play according to the size of the hand which is the body structure of the player, there are different acoustic characteristics of each instrument, so, there are many differences in classes and the students find it difficult to learn.

In this study, we compare the traditional haegeum made by the craftsman with the carbon body e-Haegeum to confirm the practical availability of the improved instrument. And, we introduce the improved features of e-Haegeum.

## **MATERIALS AND METHODS**

### **Basic theory of sound engineering and haegeum**

**Principle of sound generation:** The sound is generally caused by a variety of causes. In the case of a musical instrument, kinetic energy or potential energy such as friction, collision, repulsion, air flow, etc., between the object and the object is converted into sound energy to shake the surrounding air molecules together. And it is a physical phenomenon that the air in the atmosphere is transmitted to the human ear by transmitting this tremor. At this time, the sound that stimulates a human ear sounds differently depending on the cause of each cause and the characteristic change of the transmission process. And the sounds thus generated and transmitted are analyzed with different characteristics (Bae, 2013; Park and Bae, 2017a, b; Lee *et al.*, 2017).

The 3 factors which analyze sound are volume, frequency and duration. These three elements are independent of each other and can be used to distinguish all sounds and to separate them. The volume expresses the intensity of the input of energy into the musical instrument or the sounding system in the began or midst of the occurrence and the music determines how strongly the instrument is played. The unit of measurement in deciBels (dB) is used to measure the amount of change in the amount of energy that is changed according to human hearing characteristics. The frequency refers to the number of times the air molecule vibrates for 1 sec per unit time. The sound generated by the instrument is not constituted by a single frequency and the reproduction of the harmonics according to the resonance structure of the musical scale and the musical instrument becomes possible. By analyzing the frequency, it is possible to analyze the size of the fundamental resonance structure, the length of the strings, the width of the plate and the mode of vibration. The next duration is the length of the sound and is used to distinguish the type and characteristics of the instrument as well as the source of the sound (Park and Bae, 2017a, b; Park *et al.*, 2016; Justice, 1985).

In this study, haegeum is classified as a rubbed string instrument and it was introduced and improved from China during the Koryo period. Even today, the prototype is made in the most well preserved form with the two strings of silk bow in the bow, the quivering of the string shaking the sounding board and the resonance tube amplifying the sound.

**Haegeum:** Haegeum is a rubbed string instrument, that makes a sound through friction by using a bow made of horsehair between two strings in parallel and strings stand vertically on the body. By adjusting the tension of two lines vertically connected with the opposite hand moving the bow, the score will be adjusted to play. Haegeum was introduced to Korea in the Goryeo period and became a Korean musical instrument. Because the resonance body is small and the sound like clogged nose, also called “Cangcang-ee” or “Kengkeng-ee”. And the size of the musical instrument is smaller than that of Ajaeng and Gayagum, making it easy to carry. Also, unlike instruments such as Gayagum and Geomungo which are plucked with the fingers stringed instruments, that can continue play the strings by dragging the strings with the bow. This character is similar to wind instruments, that has been organizing with wind instruments, since, Chosun period. The acoustic gaps are filled in the ensemble of wind instruments that have limitation of breathing, it must be organized with wind instrument and haegeum ensemble (Bok-Kon, 2010; Choi, 2008; Yoon-Joo, 2015; Hwan, 2014; Suok-Kim, 2014; Oh, 2009).

The structure and shape of Haegeum are shown in Fig. 1. Haegeum stands vertically on the body (resonance body) vertically (Jud Dae), puts 2 strings through Juddae and the body barrel (JuA) and bows between the 2 strings. It is said that there are 8 kinds of materials to make the haegeum and the cast iron and Gamjab-ee are usually made of metal, the stone of Okdol which reinforces the bottom of Juddae, the string is silk, the bamboo of Juddae and the bamboo and the *lagenaria leucantha*. It is said that the rosin applied to the leather corresponds to the soil, the leather band of the handle of the rope handle. In the early days when haegeum was produced, the body was made by using the root portion of bamboo or between the nodes of bamboo. Recently, however, the wood is compacted and hardened and processed (Park and Bae, 2017a, b; Bok-Kon, 2010; Choi, 2008; Yoon-Joo, 2015; Hwan, 2014; Suok-Kim, 2014; Oh, 2009).

Improved haegeum also improved the traditional haegeum to change the tone, change the structure of the musical instrument and change the playing method.

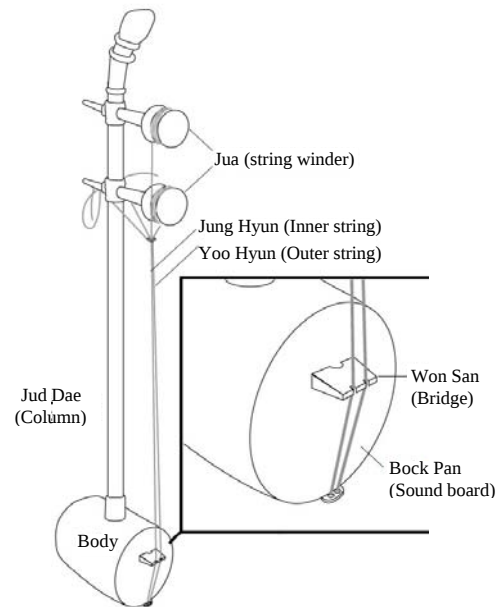


Fig. 1: Structure and shape of haegeum

Looking at the improvement section of the traditional haegeum, the use of leather and wood together with the wooden bamboo tube increased the resonance and resonance of the sound and at the same time, the soft tone became possible. In addition to this, it can be said that the change of the material of bows, the changing shape of winder and the use of the open strings. In addition, the existing silk string was replaced with a steel string to soften and enrich the tone. However, it is difficult to express the characteristic part of traditional music. And the most important part of these improvements, the pickup microphone is installed, so that, the sound of the instrument can be directly received, it is the part that changed the volume so that it does not lack in volume (Park and Bae, 2017a, b; Bok-Kon, 2010; Choi, 2008; Yoon-Joo, 2015; Hwan, 2014; Suok-Kim, 2014; Oh, 2009).

**Characteristics of carbon body haegeum:** The improvements of proposed e-haegeum is summarized as follows. First, the body of the electronic haegeum which amplifies the sound through the resonance was made of carbon filament material by 3D printing. By this method, the resonance frequency of the body can basically be set to be the same. Due to the nature of the carbon material, the floating ground of the electronic musical instrument can be efficiently solved. Secondly, we improved the structure of the worm and worm gear which is not influenced by temperature and humidity by improving the structure of the worm gear of Fig. 2. In the case of

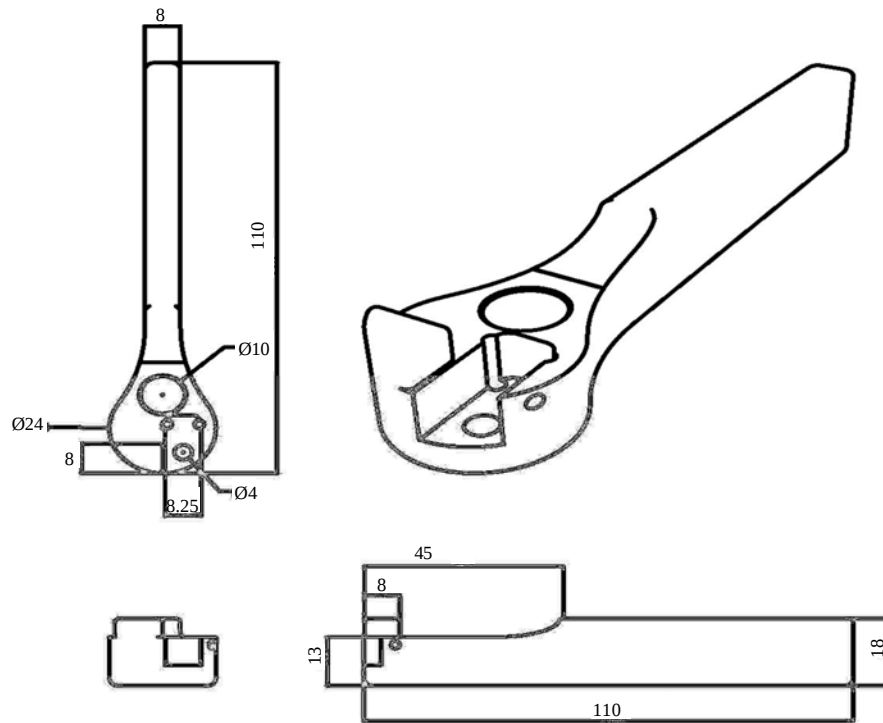


Fig. 2: Improved structure of string winder (Jua)

traditional haegeum, glue is used to fix the Jua to the vertical shaft. If the temperature and humidity of the glue are high, then difficult to move and tune if the temperature and humidity are low, there is a drawback that it is loose and difficult to tune and manage. That can also adjust the depth to be fixed to the Juddae, it has been improved, so that, it can be played comfortably with a small player like a child or with a big hand like an adult man. Third, there is an improvement in selecting the position of the acoustic sensor according to the assembly of the vibration plate and the body and the position of the original. Conventional electronic musical instruments amplify a sound source by incorporating a small microphone or using a microphone outside. At this time, the acoustic characteristic differs depending on the musical instrument and the sound source radiation pattern of the musical instrument is different, so, it takes a lot of time to harmonize with the acoustic system. However, in the proposed electronic hull, the acoustic sensor is built in to allow the whole band to be received in an even sound without excessive vibration of the strings. And the position was selected by vibration mode analysis of the vibration plate according to the position of the source. Also, it was confirmed that even if these changes are produced mechanically by non-experts, the acoustic characteristics are obtained uniformly and constantly.

**Analysis of haegeums sound:** In order to analyze the sound of the traditional haegeum and the proposed carbon haegeum, one performer played two haegeum under the same conditions. We performed without audience in 200 seats. And the temperature was about 22°C and the humidity was about 50%. Traditional haegeum is a haegeum produced by the famous Korean traditional musician Ryu and the proposed electronic haegeum use the electric mode of the popular type of carbon filament body. The sound sources of haegeum were sampled at 44 kHz and quantitated by 24 bit/sample. The same scales were analyzed to analyze the sound source accurately.

Figure 3 is the haegeum sound made by the Master Ruy, the right side is the proposed electronic haegeum sound, that shows the result of analyzing source in the frequency domain. It was analyzed that the main frequencies that occurred were responding similarly. In addition when the octave increases, the slope of the sound source decreases more than that of the normal mode. In the case of electronic haegeum, it is possible to control the attenuation rate and volume of the volume, so that, it can be confirmed that there is no difference in the sound with the traditional haegeum. Furthermore, in the case of electronic haegeum, it can be confirmed that the harmonic structure is more dense. This shows that the resonant sound is well amplified through the electronic

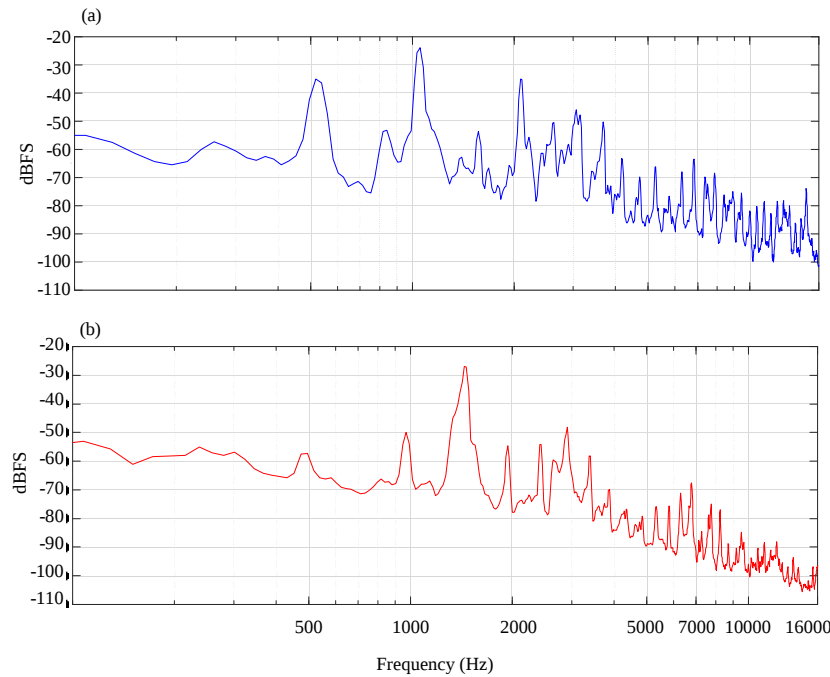


Fig. 3: Acoustic analysis of: a) Traditional haegeum and b) Electronic haegeum

circuitry. In addition, the phoneme width of the harmonics playing a single musical scale was similar and it was confirmed that the response in the band of 3-4 kHz which sounds particularly well to the human being is smooth and fine.

## CONCLUSION

Traditionally, traditional stringed instruments are made of wood. Wood has the advantage of being easy to obtain with materials and easier to process than other materials. However, compared to these advantages, it is difficult to guarantee quality as a musical instrument when mass production is performed. Haegeum, one of the traditional stringed instruments in Korea has been played and conveyed to the present day in a state of preservation of the original form and production method. However, for the public to learn and play haegeum, sound quality is good and improvement is needed to facilitate the distribution and management of similar instruments. In the meantime, the improved haegeum was lower in sound quality than the traditional haegeum. The tone and quality were different each other and there was a great difficulty in learning and playing the instrument.

In this study, we compared the sources of traditional haegeum and hybrid electron haegeum. The body of proposed haegeum is made of carbon filament material using 3D printer and it has excellent strength and

characteristic of carbon material, so that, it retains the characteristic similar to bamboo root which is the first traditional material and the sound is also well controlled compared to traditional haegeum. And easy tuning through the improvement of the winder and also it is possible to supply good quality musical instruments by taking advantage of the advantage of adjusting the position of the stringer and the vertical bar to match the size of the player's hand. Above all, it is advantageous to produce sounds of similar quality in terms of haegeum sound. In the electronic mode, it is easy to control so that the sound of the haegeum can be well displayed in the concert with other musical instruments or in the performance when the volume is abundant and various changes can also be produced through the adjustment of the tone. In this study, we introduced a carbon filament body electron haegeum which has various advantages in acoustic aspect, structure and management.

## RECOMMENDATION

In the future, we will further study the improvement of the electronic circuit, so that, the sound similar to the sound source of traditional haegeum can be realized.

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