The Effect of the Khong Wong Yai Parameters on Sounds by FEM

Joompon Bamrungwong¹ and Pattaraweerin Woraratsoontorn²

1 Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut’s University of Technology North Bangkok, 1800 Bangkok, Thailand
2 Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut’s University of Technology North Bangkok, 1800 Bangkok, Thailand
E-mail: joompondej@gmail.com

Abstract. The Khong Wong Yai is called Gong in English but different in number to tune the sounds, beeswax with not exactly amount is pasted under the bossed. It is a Thai’s percussion instrument usually involves some kind of striking on nipple gong. It is composed of 16 units of Gong as a circle of a rattan frame. The bossed or nipple gong embossed in center of a gong generates one key sound. Player has to percuss the gongs to create the rhythm with two hard rubber mallets or soft padded mallets as beaters and sits in the middle of the circle. The sound of the gong usually involves vibration of its own structure. The aim of this analysis is to study the eigen modes and find out the important parameters to generate sound frequency which are excited on the bossed or nipple gong by finite element analysis. In this paper the inertia relief method is to study the sound frequency of the Gong. The results show that the diameter of the Gong, the thickness of flange and the thickness of cylinder formed the Gong are important parameters which can be optimized to obtain the correct sound key.

1. Introduction

The melodies are very necessary to all forms of music of all cultures. As well known the percussion instrument is important to generate them. The percussion instrument often involves some kind of striking to the object and then makes vibration that produce the sound. Although there are so many percussion instruments for traditional Thai musical instruments, the khong wong yai is a type of the percussion instrument that is structured as the circle with the many gongs in a rattan frame. It is frequently occurred in the Piphat ensemble to provide the skeletal melody with the other instruments of the refined ensemble[1]. The bossed or nipple gong is a gong that is embossed in center. The sixteen key sounds are generated from the sixteen different sizes bossed gongs in a rattan frame. The gongs are individually tuned with beeswax under the circular metal disc. A player sits in the middle of the circle and holds two hard rubber mallets or soft padded mallets for hitting the gong for beating. However, the engineering principles were not being applied to design and produce the gongs by handmade, while they were constructed with the experience and skill of the maker. Bor-Tsuen Wang studied the Chinese’s gong by finite element method and attempt to verify by experimental modal analysis (EMA)[2]. However, the theory of Euler-Bournoulli equation is often used for studying the vibration of the object that four parameters are needed for the solution of the equation for only fixed supports[3]. Actually, the gong is suspended vertically by a cord passed through two holes adjacent to the top rim of the bowl structure that can be assumed as free in the space not fixed support. Thus, it is impossible to determine the eigen modes of the gong by Euler-Bournoulli beam theory[4,5]. This
research proposed to investigate the modes shape characteristics of the gong’s sound with no constraint body using inertia relief by FEM. The simulation result achieved was validated by comparison with the experiment result.

2. Materials
Basically, an individually gongs is adjusted the key tone with beeswax pasted under the circular metal disc. In this study, the first and the last gongs comprised in the khong wong yai without beeswax thoroughly were analyzed to generate the most difference of frequency among the gongs. The first bossed gong is larger size than the last one which can generate the lower frequency than another. Although the general shape of both gongs are same, their sizes are different. Therefore, the eigen modes were validated by sound spectrum analyzer. However, the 3D model actual size the gongs were created for analysis by Ansys finite element software. The khong wong yai is shown Fig. 1(a). The first gong and the last gong used in this study is shown in Fig. 1(b).

In this investigation, both bossed gongs were made of the brass. The engineering data of material properties were used for FEA has density 8600 kg/m3, Young’s modulus 1.06x105 MPa and Possion’s ratio 0.31.

3. Method
Due to the vibration of the Khong Wong Yai is a free vibration that can be considered with no constraint on it. In previous research[4] the inertia relief approach is combined with finite element analysis in the modeling and analysis of unconstrained systems. In this study, the commercial finite element packages ANSYS is used for analysis. The parameters have been studied is shown in Fig. 2.
The governing equation most use to explain the transverse frequency is Euler-Bournoulli beam theory that start from The equations of motion of the wooden bar can be written down using Newton’s second law of motion. Consider the Figure 2 the Gong is to the transverse direction of vibration that the deflection. The wooden bar no external force is applied and if EI(x) and A(x) are assumed to be constant, equation (1) simplifies so that free vibration is governed by

\[
\frac{\partial^2 w(x,t)}{\partial t^2} + \frac{EI(x)}{\rho A(x)} \frac{\partial^4 w(x,t)}{\partial x^4} = 0
\]  

(1)

the general solution of equation (1) can be calculated to be of the form

\[
X(x) = a_1 \sin(\beta x) + a_2 \cos(\beta x) + a_3 \sinh(\beta x) + a_4 \cosh(\beta x)
\]  

(2)

Then the frequency of wooden bar in hertz can be written in the form

\[
f_n = \frac{\beta \rho}{2\pi} \sqrt{\frac{EI(x)}{\rho A(x)}}
\]  

(3)

The sound wave propagating through an elastic medium define as speed of sound was equal to the square root of the elastic property divided by its density, and from definition of radius of gyration the equation (3) can be written in the form

\[
f_n = \frac{\theta \beta \rho}{2\pi} R(x)
\]  

(4)

Where

\[
\theta = \sqrt{\frac{E}{\rho}}
\]

\[
R(x) = \sqrt{\frac{I(x)}{A(x)}}
\]
Noted that the natural frequency is depend on constraint of the boundary conditions but this analysis the Gong is freeing vibrate can be considered no constrain on the Gong. The result from finite element will be plotted and linearized by find out the slope \( \frac{\Delta y}{\Delta x} \) then get unit per effect.

4. Results
Eight parameters of the gong were studied by FEA simulation more than 3 points as shown in the Fig. 3 to Fig. 9. From analysis results found that parameters V13, V15, H6, and L12 have high unit per effect respectively as shown in Table 1.

![Figure 3. Frequency vs Flange thickness](image)

![Figure 4. Frequency vs Edges thickness](image)
**Figure 5.** Frequency vs Flange radius

**Figure 6.** Frequency vs Flange high

**Figure 7.** Frequency vs Flange angle
Table 1. Unit per effect of Gong Wong Yai

| Parameters                          | Remark       | Unit | Unit/Effects |
|-------------------------------------|--------------|------|--------------|
| Thickness under boss_R21            | Radius       | mm   | 15           |
| Boss high_V22                       | High         | mm   | 12           |
| Cylinder perspective_A28            | Angle        | Deg  | 5            |
| High of cylinder_L8                 | High         | mm   | 5            |
| Dia. of flange_H6                   | Radius       | mm   | 72           |
| THK of cylinder_L12                 | Thickness    | mm   | 68           |
| THK of flange_V13                   | Thickness    | mm   | 168          |
| V15                                 | Thickness    | mm   | 146          |

5. Conclusion

The result show in Table 1 take a look at the Unit/Effect, from this initial study found that the thickness of the flange (v13) of the Khong Wong Yai are the key parameter influence and related to the tuning the sound frequency of the Khong Wong Yai. The secret of Khong Wong Yai is the
thickness of its flange (ν13 and ν15). By FEA study the sound frequency of the khong wong yai has the eigen modes generated from bending mode that is moving upwards and downwards of the entire flange (top surface) of the bossed gong. The researcher recommend that drill the holes to hold the gong that it should be far a bit from the flange of embossed surface to avoid fast decay of the sound. In this study revealed that Khong Wong Yai needs beeswax for tuning the key sound always, The Ranat or the Xylophone can be designed with no the beeswax. Thus, Khong Wong Yai, It is impossible to make it without beeswax by all parameters are considered as linearity.

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