MODELING AND ANALYSIS OF SOMPOTON VIBRATOR USING CANTILEVER BEAM MODEL

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ABSTRACT

Sompoton is one of the famous traditional musical instruments in Sabah. This instrument consists of several parts with the vibrator being the most important of all. In this research, the vibrator is modeled as a cantilever beam with uniformly distributed mass. Using this model, the fundamental frequency is analyzed using single degree of freedom system (SDOF) and exact analysis. The vibrator made from aluminum and brass is fabricated in different dimensions and is excited using constant air jet to obtain its fundamental resonance frequency. The fundamental frequency obtained from the experiment is compared with the theoretical values calculated based on cantilever beam model, SDOF system and exact analysis theories. It is found that the exact analysis gives closer match to the experimental results compared to SDOF system for aluminum vibrator. However, result for brass vibrator showed that SDOF system gives closer match compared to exact analysis. In both test, experimental and theoretical results exhibit the same trend but differ in magnitude. To overcome the differences in both theories, a correction factor is added to the theoretical formulation to account for the fabrication errors.

ABSTRAK

MODEL DAN ANALISIS PENGGETAR SOMPOTON DENGAN MENGGUNAKAN MODEL RASUK TERKAPIT-BEBAS

Sompoton merupakan salah satu alat muzik tradisional yang terkenal di Sabah. Alat muzik ini terdiri daripada beberapa bahagian di mana penggetar (vibrator) yang dikenali sebagai sodi merupakan bahagian yang paling penting. Dalam kajian ini, sodi dimodelkan sebagai rasuk terkapit-bebas (cantilever beam) dengan jisim teragih seragam. Melalui model ini, frekuensi asas dianalisis dengan menggunakan sistem satu darjah kebebasan (single degree of freedom system, SDOF). Penggetar yang diperbuat daripada aluminium dan loyang dalam dimensi yang berbeza digetarkan dengan menggunakan arus udara berterusan daripada jet udara untuk mendapatkan frekuensi resonans asas. Frekuensi asas yang diperolehi daripada ujikaji dibandingkan dengan nilai-nilai teori yang dikira berdasarkan model rasuk terkapit-bebas, sistem SDOF dan teori analysis tepat (exact analysis). Keputusan menunjukkan bahawa dalam ujian untuk penggetar aluminium, analisis tepat memberikan keputusan yang lebih dekat dengan data ujikaji berbanding dengan analisis sistem SDOF. Ujian untuk penggetar loyang pula menunjukkan keputusan yang berlawanan di mana analisis SDOF memberikan keputusan yang lebih dekat dengan data ujikaji berbanding dengan analisis tepat. Dalam kedua-dua ujian, keputusan ujikaji dan teori mempamerkan trend yang sama tetapi berbeza dari segi magnitud. Untuk mengatasi perbezaan tersebut, faktor pembetulan (correction factor) ditambah ke dalam formula teori untuk menghapuskan ralat-ralat yang muncul dalam proses penghasilan penggetar.

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LIST OF ABBREVIATION

SDOF	Single Degree of Freedom System
CNC	Computer Numerical Control
PIV	Particle Image Velocimetry
FFT	Fast Fourier Transform
ACE	Acoustic Converting Efficiency
WTIW	Web-based Traditional Instrument Workshop

LIST OF SYMBOLS

m = One third of the mass of the beam

c = Damping coefficient

k = Stiffness of the beam

F_0 = Amplitude of the excitation force

ω = Angular frequency of excitation

x = Displacement of the free end

t = Time

M = Bending moment

I = Second moment of inertia

E = Modulus of elasticity

R = Radius of curvature

y = Deflection at the free end

f = Frequency

α = Constant

C = Constant

B = Constant

λ = Solutions for a cantilever beam free vibration

$\phi_n(x)$ = Mass normalized eigenfunction for the nth mode

$\eta_n(t)$ = Modal coordinate of the cantilever beam for the nth mode

ζ = Damping ratio

c_c = Critical damping

I_t = Mass moment of inertia of the tip mass

M_t = Tip mass

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia is a developing country and Sabah is the second largest state which is richly blessed with natural diversity and unique heritages. It is important to preserve the cultural heritage at the same time moving towards developing country. Sabah is renowned for its cultural diverse indigenous communities of more than 30 ethnic groups. The largest ethnic group in Sabah is KadazanDusun. The sompoton is undoubtedly belongs to their cultural heritage and it also serves as an attraction in tourism. In this chapter, background of traditional musical instruments in Sabah is discussed. Sompoton will be introduced and the research statement, objectives and contribution of this study will also be included.

1.2 Traditional Musical Instrument

It is hard to trace back the historical background of the very first musical instrument. However, it is believed that the creation of the musical instrument happened at the same time with the beginning of human culture. Therefore, not surprisingly that, many early musical instruments were made from animal skins (e.g., ground-harp/ground-zither), bone (e.g., scrapers), wood (e.g., bullroarer), shell, and other materials (Lawergren, 1988).

The early musical instruments were closely related to hunting implements or were by-products of hunting (Sachs, 1977). The musical instruments can be used in numerous ways as part of hunting activities such as providing the capability to imitate animal sounds for calling quarry; to frighten animals to run towards traps; as signal tools enabling communication between distant hunters and even can be used as weapons (Lawergren, 1988). Other than that, traditional musical instrument are commonly used in spiritual event, war, and other cultural events. The development of human culture later evolved the musical instruments into

producing melodies for entertainment and relaxation. With the passage of time, musical instrument were then developed into modern instrument which is more popular among today's young generation.

Traditional musical instrument can be found in many countries. It is developed and spread out to other region when there is contact among civilizations. Traditional musical instrument mostly were originated from the local natives. China for example, is one of the countries which are rich in traditional musical instruments. Guqin, erhu, guzheng, pipa, liuqin, sheng are parts of the traditional musical instruments which can be found in the country.

Music has indeed become an important part of human's lives. However, to preserve the musical instruments from generation to generation, it requires a lot of research and efforts from not just the academic researcher, but also the state and national government. This chapter introduces the traditional musical instruments of Sabah called sompoton. The problem faced by this local traditional musical instrument is presented here. Also included in this chapter is the review of the current acoustic research on traditional musical instrument, traditional musical instruments of Sabah, description of sompoton, research statement, objectives, and contribution.

1.3 Current Acoustic Research on Traditional Musical Instruments

To date, not much research have done on traditional musical instruments. However, efforts put on this field are still encouraging. Erkut er al., (2002) had measured and analyze the sound generated from a Finnish traditional musical instrument, namely Kantele. They found that most characteristic features of the unique timbre are caused by the bridgeless string termination at one end and the knotted termination around at the other supporting end. They formulated a computational model of the instrument and made the algorithm efficient for real-time synthesis to simulate the features.

Kapur *et al.* (2005) described the systems for capturing gestures from an artist performing North Indian traditional musical instruments named tabla, dholak and sitar. They modified the traditional musical instruments using sensor technology

and microcontrollers to digitize the performance. This enabled them to use computer to synthesize sound and generate visual meaning. In Japan, a Japanese traditional bamboo flute is measured and studied in order to understand the important phenomena of sound production (Someya and Okamoto, 2007). They managed to measure the periodical flow near a hole of the bamboo flute. The flow was found to go into and out from the flute. They also visualized the flow of the bamboo flute when it is played by human and discovered that different instructors had unique methods of playing the instrument.

A considerable amount of literature has been published on characterized the acoustic properties of the wood to make a good quality Ranad bars and resonator box in Thailand (Rujinirum *et al.*, 2005). The physical and mechanical properties of the woods studied in this research were measured. The results showed that the high sound refraction coefficients were crucial factors of the Ranad bar properties. Taiwanese researcher studied the way to preserve their traditional musical instrument jaw's harp and learned the way to increase the interest from the young students (Liu *et al.*, 2012). They designed web-based traditional instruments workshops (WTIW) and implemented it in a practicum course of making the traditional musical instruments. Results showed that digital archive can help in motivating students to learn musical instruments making and help in preserving the culture.

Gamelan, an Indonesia traditional musical instrument is modeled and studied (Suprato *et al.*, 2009). They proposed to construct gamelan models by creating Gamelan Frequency Modeling. Two frequency Balungan models were proposed. First model is using average value and other one is using average value in the densest area. Back to this country Malaysia, Zainal *et al.* (2009) carried out a research on Malay traditional musical instrument called angklung to study the pitch and timbre determination of it. They found that the pitch of angklung is closely related to the fundamental frequency of air resonance in the bamboo tubes of the angklung rattles. The pitch can be estimated by calculating the fundamental frequency with the information from the length and diameter of the closed cylinder air column of each rattle.

All these researches on traditional musical instrument are believed to be just a part of the researches which have been done or still ongoing throughout the world. It is affirmative and it is important to continue and improvise the efforts on this field.

1.4 Traditional musical instrument in Sabah

It is important to preserve the cultural heritage at the same time moving towards a developed country. Malaysia, as one of the developing countries which forging ahead to be a developed country, still retain its nature diversity and unique heritages, especially in its second largest state Sabah. Sabah is well known for its cultural diverse indigenous communities of more than 30 ethnic groups. Musical instruments are undoubtedly one of the important cultural heritages. There are plenty of traditional musical instruments that play an important role in almost all of the social activities among the local native.

The music of Sabah, Malaysia is closely bound up with the daily lives and cultural traditions of the diverse ethnic cultures of Sabah. It can be found in many forms like ritual music (for birth, marriages, harvest festivals, and deaths), love music, battle songs, storytelling songs, among others. The musical instruments of Sabah can be distinguished with four sound-generators, namely idiophones, membranophones, chordophones and aerophones (See Table 1.1).

Table 1.1: Musical instrument classification scheme

	Major class	Examples
1	Idiophones: Vibrating rigid object	Gongs; Kulintangan; Tagunggak (Tagunggu); Bungkau (Turiding); Gabbang; Batil; and Wooden "Castanets"
2	Membranophones: Vibrating stretched membrane	Gendang; and Rebana
3	Chordophones: vibrating stretched string	Biola; Tongkungon; Sundatang; Gambus; and Violin
4	Aerophones: Vibrating air	Kata batang; Suling and Turali; Sompoton; and Kungkuvak

Few researches have been done on these local traditional musical instruments. Batahong (2006) studied the acoustic properties of kulintangan and is currently studying on the other local musical instrument- sundatang. Ong and Dayou (2009) initiated the study of frequency analysis of sound from local traditional musical instrument- sompoton. They measured and analyzed the sound produced and found that the generation of harmonic frequency follows the open-end pipe models.

1.5 Sompoton and its sound excitation

Among the local Sabah traditional musical instruments, sompoton plays a significant role that contributed to the local native cultural traditions. The sompoton, particularly popular in the KadazanDusun villages, is one of the famous cultural heritages where it is highly used as an attraction in tourism and also traditional festival. Sompoton is a very personal instruments of Sabahans and is normally played for relaxation, times of important events in life of individual (such as awaiting a birth of child) or as a mean of communication with nature.

Sompoton consists of three parts- acoustic chamber, vibrator locally known as sodi and bamboo pipes (Marasan, 2003; Figure 1.1). This musical instrument is made from natural resources which include bamboo pipes, dried gourd, and palm tree. The eight slender bamboo pipes fitted together inside an emptied gourd which

serves as the wind chest. To play the sompoton, the performer needs to produce a continuous stream of air by sucking and blowing. The air resonance in the gourd is then act as an air jet passing through the vibrator making it to vibrate and thus producing audible sound. Musicians can create melody by covering and uncovering the opening of the three shorter pipes with right hand and small sound holes near the front and the back pipes with left hand (Frame, 1982). Figure 1.2 further illustrates the standard posture of playing the sompoton.

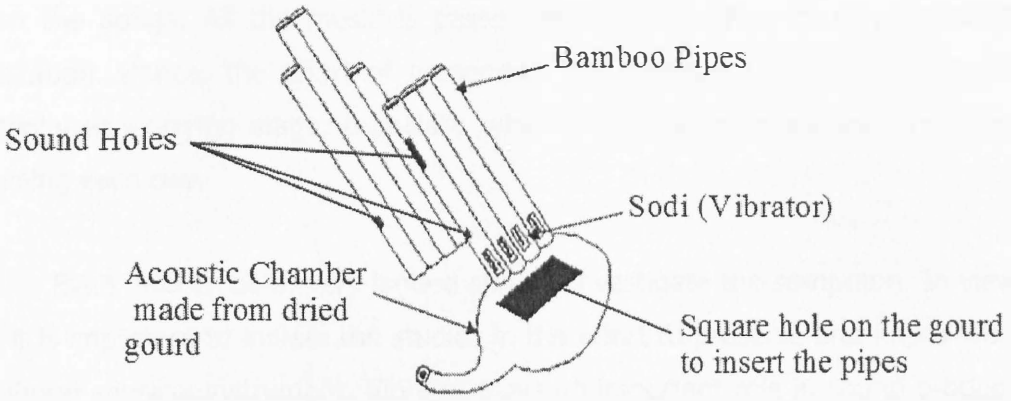

Figure 1.1: Structure design of sompoton.

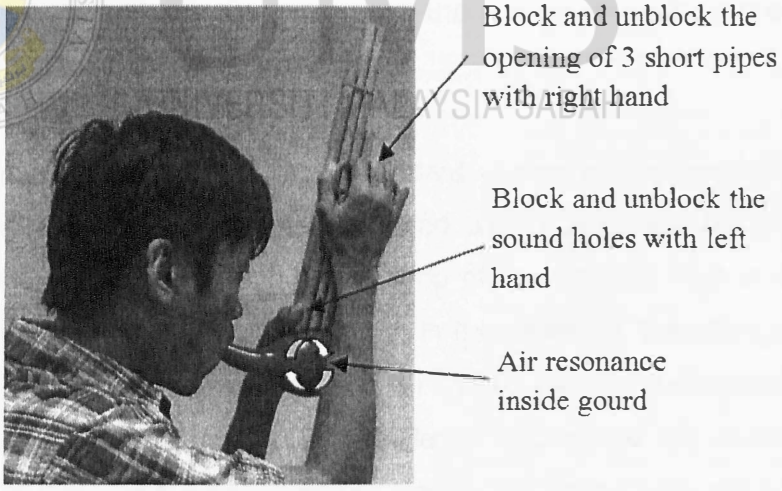

Figure 1.2: Standard posture while playing sompoton.

1.6 Research Statement

In Sabah, traditional musical instrument is mainly seen on the souvenir shops, cultural events, and within the local villages. Music schools and institutes are everywhere in the city providing services for everyone to learn musical instruments but mostly for modern musical instrument learning like piano, violin, guitars and

other popular modern instruments. Rarely can be seen a music schools teach traditional musical instruments. Therefore, it is not a surprise that the young generations are forgetting the beauty of traditional music and the importance of their cultural heritage.

In addition, most of the instrumental performer is often the craftsman who makes the instrument. The society has no system for notating its music nor written down the songs. All the music is passed down by tradition from generation to generation. Hence, the effort of preserving this traditional musical instrument is currently at worrying stage, especially when the numbers of sompoton makers is declining each day.

Even until to date, very limited studies investigate the sompoton. In view of this it is important to initiate the studies in the effort to preserve and improvise this traditional musical instrument. Vibrator plays an important role in sound production from sompoton. It is the source of the sound and without it, the sompoton cannot produce any sound. The original vibrator is made by polod which is a kind of palm tree found locally. Craftsman will cut the polod into the cantilever beam model shape with small gap in between the frames.

Existing vibrator does not have a fixed standard dimensions to produce certain sound frequency. In order to get the required sound produced by the vibrator, craftsman needs to adjust the length of the tip of the vibrator. It is only depends on the expertise of the craftsman. Therefore, in this research, the effort is putting on the sompoton's vibrator. Sompoton's vibrator length and its fundamental sound frequency will be studied and analyzed. In order to understand the sound production mechanism of the vibrator with different length, the sound data will be collected and analyzed by using cantilever beam model. The outcome of this research will provides a model of the sompoton's vibrator that enables the prediction of its fundamental frequency. With the use of this model, the fabrication method of sompoton's vibrator can use a much easier and less complicated way.

1.7 Research Objectives

There are two main objectives in this research:

i. To establish a suitable model of the sompoton's vibrator that enables the prediction of its fundamental frequency.

ii. To analyze sompoton's vibrator acoustic properties with approximate analysis and exact analysis.

1.8 Thesis Contribution

This research emphasizes the effort of preserving the local traditional music instrument-sompoton. The results of this study involves the aspect of sound frequency generation, the change of the dimension towards sound frequency, design of vibrator (sodi) and the electrical circuit modeling. Therefore, the study of musical instrument especially sompoton is now more comprehensive compare with some previous study.

This study is beneficial to the state of Sabah where the technology which lies in the sompoton musical instrument is developed and could be used as a standard to be referred in the future.Besides, with a better understanding or knowledge about sompoton, it is believed that this traditional musical instrument can attracts more people especially the young generation to learn and further study about it. Traditional music could also be commercialized to the music market and new generations. Most importantly, it could give great chance to introduce local traditional music to the music lovers around the world and pushes it to the international level.