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EFFECTS OF PLUCKING FORCE TO FUNDAMENTAL FREQUENCY OF SOUND AND BODY VIBRATION OF SAPE

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ABSTRACT

Sape is the popular traditional musical instruments in Sarawak, Malaysia. It was normally played to a form of ritualistic music to induce trance by the local indigenous people. The use of the sape has now become a social instrument to accompany dances and for entertainment. This paper investigated the effects of the plucking force on the sape's string to the frequency of sound and body vibration of the instrument. The experiment is carried out in the anechoic room, the string is plucked to generate the sound and cause body vibration. The sound and vibration were collected using a microphone and accelerometer. The data is then imported to MATLAB for analysis. The fundamental frequency (FF) is then identified after performing a Fast Fourier Transform (FFT) on the data to get the frequency spectrum. It is found that the plucking force has no effects on the fundamental frequency produced by the sound and body vibration. However, the fundamental frequency produced by three different sizes of sape in this study gave different values. The findings in this study can be used as the reference for or guideline for the sape maker, player, and future studies.

Keywords: Sape, traditional musical instrument, fundamental frequency, Fast Fourier Transform, frequency spectrum

INTRODUCTION

Sarawak is blessed with local musical arts and musical instruments from different ethnics. *Sape* or *Sapeh* is one of the most popular traditional musical instruments among local residents in Sarawak. Few researches have been carried out on local traditional musical instruments in Malaysia and most of them started with understanding the frequency characteristics of the sound production.

In peninsular Malaysia, Ismail *et al.* (2006) have studied the properties and characteristics of sound produced by kompang, Malay traditional musical instrument. Computer music synthesis is used for the analysis of the sound produced. Kompang is noted as a pitch less musical instrument and it is similar to other vibrating circular membrane instruments.

In Sabah, Ong & Dayou (2009) initiated the study on Sabah traditional musical instrument- *sompoton*. They studied the frequency spectrum produced by the sompoton and managed to compare the sound production by sompoton with open-end pipe model. Further research on sompoton was done by Wong et al. (2013) on the vibrator of the sompoton. Wong et al. study approach was based on the sound production of the vibrator of sompoton and analysed using a cantilever beam model. Different types of material were used to facilitate the vibrator of sompoton. Sound data collected was then analysed to understand the fundamental frequency spectrum. Theoretical and experimental results were compared and they managed to

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prove that the experimental result complied with the theoretical result with some deviation. A correction factor was then added to the theoretical formula.

Batahong & Dayou (2002, 2003) have done a study on *Kulintangan*, Sabah traditional musical instrument. The authors studied the fabrication process of the instrument, vibrational modes and sound frequency produced by the instrument. Batahong *et al.* (2014, 2016) also done a similar study on another type of Sabah traditional musical instruments- *Sundatang*. The research was carried out to understand the vibrational properties of the sundatang soundboard. The measurements were carried out by obtaining the FRF and modal parameters of the top plate and back plate of sundatang. The outcome of the research provides important information about the study of the quality development of sundatang.

Wong *et al.* (2017) initiated the study on sape. The study investigated the effects of the string tension to the fundamental frequency of sound and body vibration of the sape. Using three different sizes of the sape musical instrument as the research sample, the results showed that for high and medium tension, the vibration and sound samples showed similar results. However, for the low string tension, the fundamental frequency produced by the sound and vibration showed deviations. The authors concluded that the difference occurred might be due to the tendency of the instrument body to resonate only at a high frequency.

Sape is categorized as string type instrument and has a shape similar to a guitar. It is carved from a single bole of softwood, usually the Meranti and Merdang. The elongated body is hollowed out and functions as a resonator. The strings were made from the sago tree originally, but now these have been replaced by nylon or steel strings. The common sape usually has three or four strings. Figure 1 and Figure 2 shows the schematic drawing and the actual photo of a sape that was studied in this paper.

Figure 1: Schematic Drawing of Sape

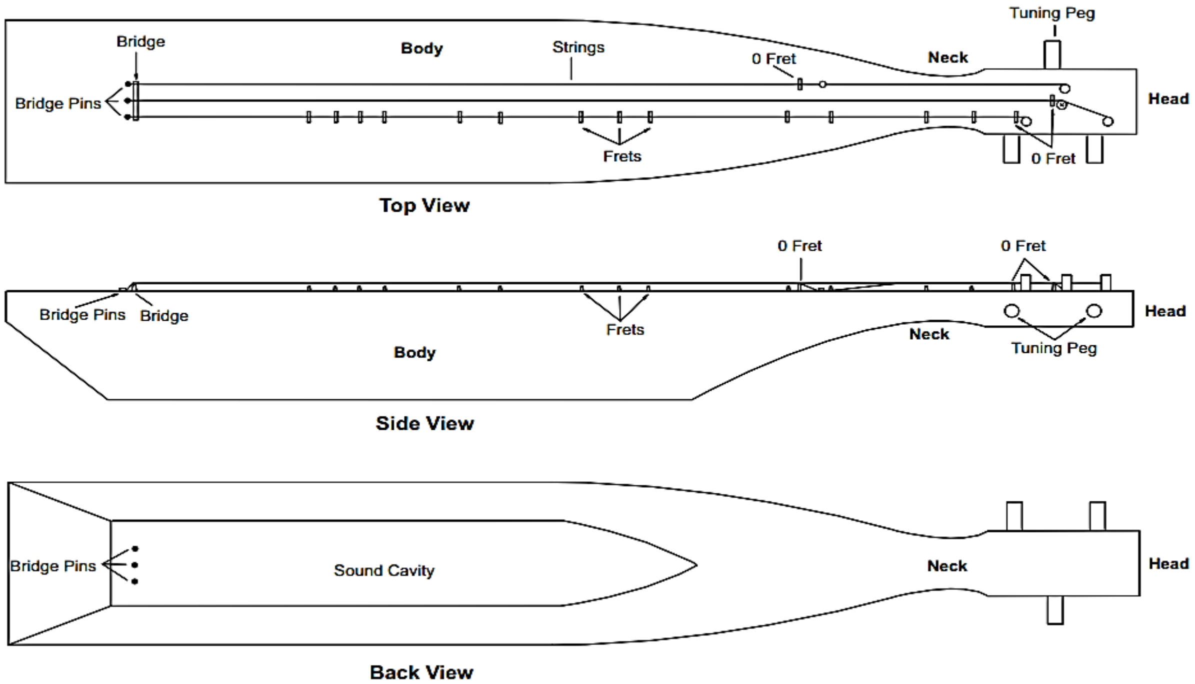

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Figure 2: Traditional Musical Instrument, Sape

The vibration of the string type of musical instrument is done by either bowing or plucking the string. For a plucked string, the displacement waves will travel in opposite directions from the point of excitation and reflected at the bridge or end of the string (Fletcher and Rossing, 1998). The waves will then interfere with each other and form a standing wave. The standing wave of the string is then vibrating in multiple harmonics hence creating the rich sound of the string instrument.

In this study, three sape of different sizes were studied to see if the plucking force will affect the fundamental sound and vibration frequency of the instrument. The harmonics produced by the instruments were also analysed.

METHODOLOGY

A laboratory experiment was conducted on three sample of different sizes of sape instrument as shown in Figure 3 in which we name it sape A (large), B (medium), and C (small). The sape is fixed on the holder to minimize the movement of the instrument and let it vibrate freely when the string is plucked. The properties of the stainless steel string used are $L = 0.78 \sim 0.8$ m and $\mu = 2.5\times10^{-4}$ kg/m. The microphone is placed above the instrument and the accelerometer is attached to the body of the instrument. The tension of the first string was tuned into constant note C5 while the other two strings were damped using a sponge to avoid unwanted resonance or vibration.

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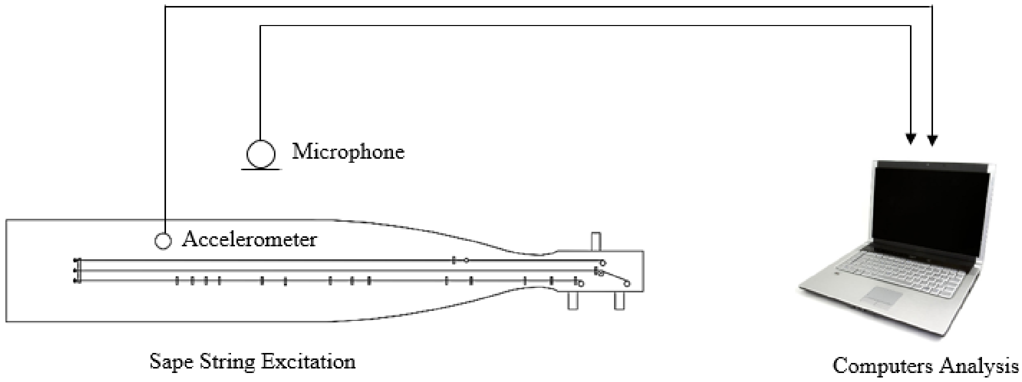
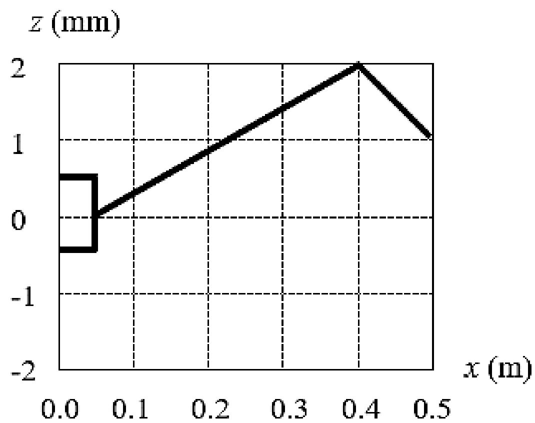
Figure 3: Experimental setup of the sound and vibration recording and data analysis



To generate the sound from sape, the tuned first string is then plucked using a guitar pick in the direction parallel to the surface of the top plate of the instrument. Figure 4 illustrates the displacement of the string where *x* denotes the axis along the string and *y* denotes the axis perpendicular to the top plate of sape. The first string is plucked to the *z*-direction parallel to the top plate. To differentiate different plucking forces, the displacement from its original *z* position by guitar pick is set at 1mm, 2mm, and 3mm for low, medium, and high plucking force respectively. The plucking point is fixed at one point which is indicated on the instrument body with a marker. The sound generated is recorded by the microphone and the response of the body vibration from the plucked string is captured by the accelerometer. The whole experiment process is carried out in an anechoic room to avoid unwanted background noise.

Figure 4: Displacement of the plucked string.



All of the data obtained from the experiment is then further analyzed by using MATLAB software available in the computer. The sound and vibration data recorded is imported to MATLAB and is analyzed by using Fast Fourier Transform (FFT) to obtain the frequency spectrum. The peak of the fundamental frequency and its harmonics are then identified and recorded.

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RESULTS AND DISCUSSION

In this section, the sound and vibration data measured and collected from the plucked string is analyzed and compared. Three sape of different sizes were used as a sample in this study. The frequency spectrum of the sound and vibration is generated by performing a FFT. 2^{17} (131072) samples from the sound and vibration file are extracted. In order to obtain the fundamental frequency, we used data cursor to get the *x*-value of the first obvious peak. The same method also used in finding the corresponding harmonics frequencies (up to 10th harmonics). The harmonics can be proved by using the ratio analysis in Equation (1)

$$\text{ratio} = \frac{f_i}{f_0} \quad (1)$$

where f_0 is the fundamental frequency or first harmonic and f_i is the consequence frequencies or harmonics, where $i = 2,3,4,5...n.$ The geometric sequence of the ratio of the fundamental frequency to the consequences frequencies can be listed as f_0, 2 f_0, 3 f_0, …n f_0.

Figure 5 shows a sample of frequency spectrum after FFT for both sound and vibration data. The first harmonic is always thought to be the highest peak, but this is not always the case for the real date spectrum. From the frequency spectrum in Figure 5, the highest peak is observed to be at the 3rd harmonic. From Figure 6, it can be seen that both the frequency spectrum for sound and vibration overlapped. The fundamental frequency and its harmonics are located at the same value.

Table 1 shows the results obtained from the frequency analysis of sound and vibration frequencies for the three sample of sape. As can be seen from the table, no significant difference was found between sound and vibration's fundamental frequency and its harmonics. This happened to all the three different sizes of sape. The frequencies generated from sound and vibration measurement appeared to be unaffected by the plucking force.

The plucking force is proved to have no effect on the frequency of sound and vibration of the instrument body. This can be explained by the theoretical formula of the frequency, *f* generated by a string.

$$f = \frac{\sqrt{\frac{T}{\rho}}}{2L} \quad (2)$$

where *T* is the string tension, ρ is the linear density of the string, *L* is the string length. Equation (2) stated that the frequency produced by the vibrating string is depending on the length, tension and linear density of the string.

However, the result frequencies of sound and vibration collected from the three different sample of sape are found to differ from each other. Even though the difference in fundamental frequencies only in the average of 3 Hz, this interesting finding can serve as the starting point for the future research on the effects of the sape size to the sound and vibration produced

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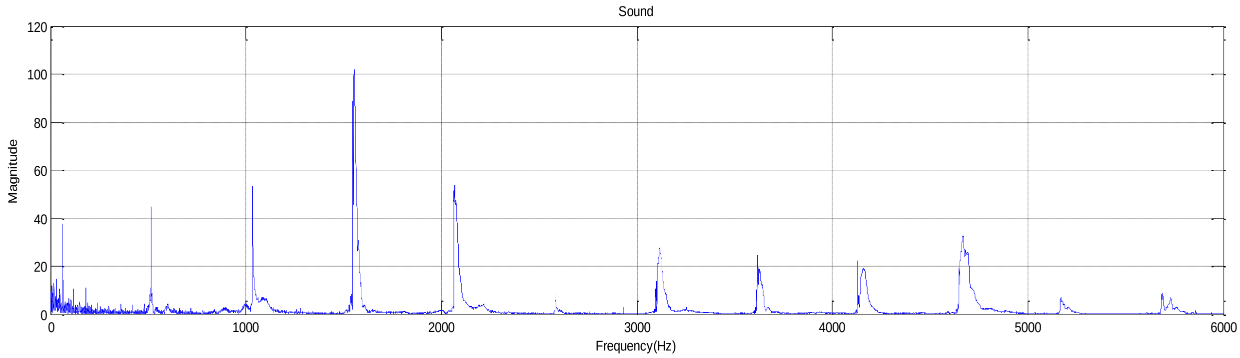
Figure 5: Frequency spectrum of the sound (blue) and vibration (red).



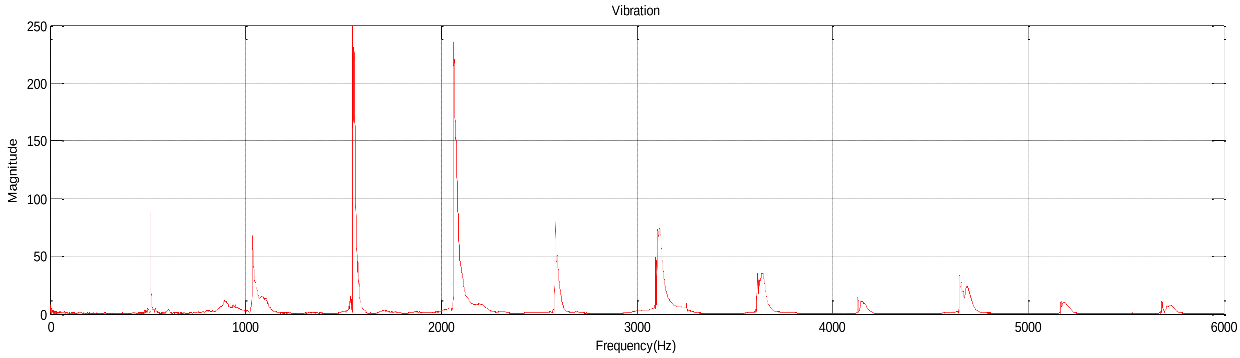


Figure 6: Frequency spectrum of sound and vibration

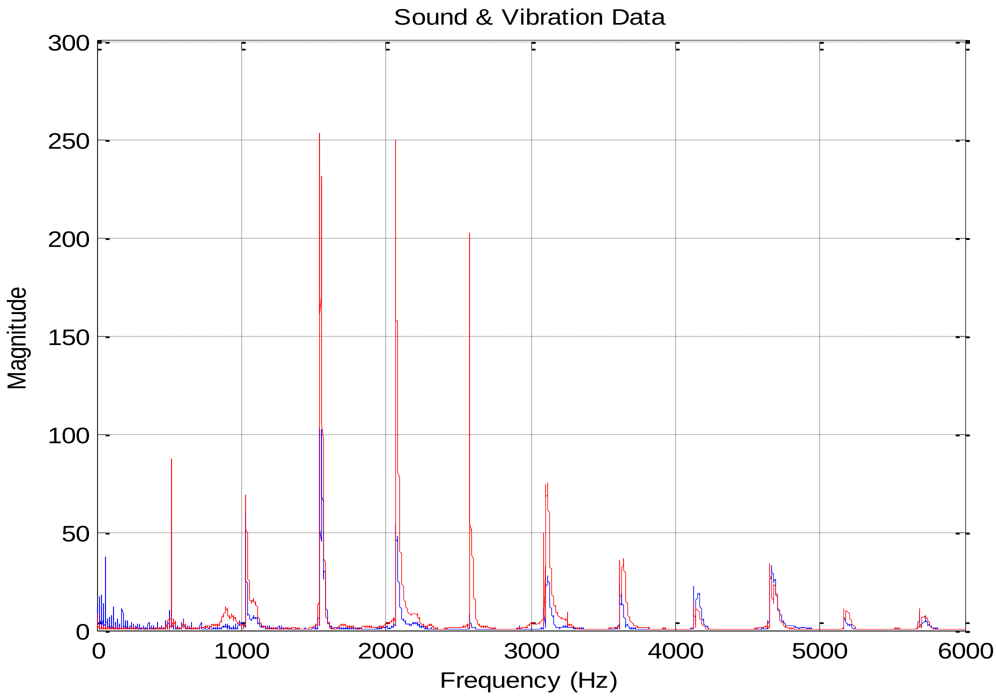


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Table 1: Sound and vibration frequencies for large, medium and small Sape.

(a) Fundamental frequency to 5th harmonics

Size	Plucking Force	Harmonics Frequency (Hz)														
		FF			2nd			3rd			4th			5th		
		Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.
Large	High	519.60	519.70	0.10	1039.00	1038.00	1.00	1558.00	1558.00	0.00	2079.00	2083.00	4.00	2602.00	2598.00	4.00
	Medium	519.40	519.50	0.10	1039.00	1038.00	1.00	1559.00	1558.00	1.00	2079.00	2079.00	0.00	2598.00	2598.00	0.00
	Low	519.30	519.40	0.10	1039.00	1038.00	1.00	1558.00	1558.00	0.00	2078.00	2077.00	1.00	2597.00	2597.00	0.00
Medium	High	516.20	516.10	0.10	1032.00	1032.00	0.00	1554.00	1548.00	6.00	2067.00	2064.00	3.00	2582.00	2581.00	1.00
	Medium	517.40	516.80	0.60	1034.00	1034.00	0.00	1552.00	1552.00	0.00	2068.00	2068.00	0.00	2585.00	2586.00	1.00
	Low	516.80	516.80	0.00	1034.00	1034.00	0.00	1550.00	1550.00	0.00	2067.00	2067.00	0.00	2585.00	2584.00	1.00
Small	High	521.80	521.80	0.00	1045.00	1045.00	0.00	1569.00	1567.00	2.00	2090.00	2092.00	2.00	2614.00	2613.00	1.00
	Medium	521.50	521.70	0.20	1045.00	1045.00	0.00	1568.00	1568.00	0.00	2090.00	2090.00	0.00	2614.00	2614.00	0.00
	Low	522.40	521.70	0.70	1045.00	1045.00	0.00	1568.00	1568.00	0.00	2089.00	2088.00	1.00	2613.00	2613.00	0.00

(b) 6th to 10th harmonics

Size	Plucking Force	Harmonics Frequency (Hz)														
		6th			7th			8th			9th			10th		
		Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.	Sound	Vibration	Diff.
Large	High	3120.00	3128.00	8.00	3637.00	3638.00	1.00	4160.00	4159.00	1.00	4677.00	4689.00	12.00	5207.00	5206.00	1.00
	Medium	3119.00	3120.00	1.00	3637.00	3637.00	0.00	4158.00	4159.00	1.00	4682.00	4679.00	3.00	5202.00	5201.00	1.00
	Low	3117.00	3118.00	1.00	3637.00	3636.00	1.00	4158.00	4157.00	1.00	4678.00	4676.00	2.00	5197.00	5197.00	0.00
Medium	High	3117.00	3116.00	1.00	3616.00	3641.00	25.00	4130.00	4130.00	0.00	4668.00	4650.00	18.00	5168.00	5185.00	17.00
	Medium	3110.00	3109.00	1.00	3622.00	3622.00	0.00	4143.00	4143.00	0.00	4667.00	4658.00	9.00	5185.00	5185.00	0.00
	Low	3101.00	3101.00	0.00	3619.00	3619.00	0.00	4136.00	4136.00	0.00	4655.00	4654.00	1.00	5174.00	5174.00	0.00
Small	High	3136.00	3136.00	0.00	3671.00	3658.00	13.00	4184.00	4190.00	6.00	4707.00	4706.00	1.00	5238.00	5231.00	7.00
	Medium	3136.00	3136.00	0.00	3659.00	3659.00	0.00	4183.00	4184.00	1.00	4706.00	4705.00	1.00	5229.00	5229.00	0.00
	Low	3135.00	3135.00	0.00	3658.00	3659.00	1.00	4182.00	4181.00	1.00	4703.00	4704.00	1.00	5226.00	5227.00	1.00

CONCLUSION

This research continues the study on the Sarawak traditional musical instrument, sape. The research is focused on the effects of the plucking force to the fundamental frequency of the sound and body vibration of the instrument. Three sape made from different sizes were tested by collecting the sound and vibration generated after the string is plucked with different plucking forces. The results of the study show that the fundamental frequency of the sound and vibration showed no obvious difference. The string which is plucked at different plucking force willa generate the sound and vibration on the instrument body at the equal frequency. However, the size of the sape seems to give the difference in terms of fundamental frequency produced. These findings can provide important information on the future research on the sound production of different size of sape.

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