International Journal of Research in Engineering, Science and Management
Volume 5, Issue 10, October 2022
https://www.ijresm.com | ISSN (Online): 2581-5792

Art Meets Science

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***Abstract*: The project consists of integrating studies related to the ancient musical instrument of Kendara. It studies the Kendara, a heritage musical instrument from the state of Odisha, with respect to its historical, geographical & economical aspects. In addition, all musical instruments have a relationship with physics and mathematics. The project also delves into this relationship for both the Kendara and Tabla, the most popular percussion instrument used in Indian classical music.**

***Keywords*: Arithmetic progression in music, Kendara, Music & Mathematics, Music & Physics, Odisha heritage musical instruments.**

1. Introduction

The objective is to integrate the subjects of history, geography & economics in the study of the ancient musical instrument Kendara. In addition, the project attempts to study the Kendara from the perspective of physics and mathematics to understand the inter-relationship between art and science and demonstrate that both are two sides of the same coin.

The project attempts to conduct qualitative research to understand the physical & functional features of the Kendara using mathematical concepts such as harmonics, geometry, architecture, sequences, and progressions. The project also sought an architect's input on the design aspects such as physical appearance and geometry of the Kendara. Another key objective was to study the applicability of the relationship between arts & science to another family of musical instruments, in this case the percussion-based Tabla.

2. Kendara

A. An Overview

Fig. 1. String instruments of Odisha

Music is the heart and soul of Odisha. String instruments like the Veena, Kendara, Sarangi, Ektara, Behela, Dhenka are well known throughout the state. Kendara is similar to Ektara. It is a type of bowed chordophone [3], developed in 10th century Asia. The Kendara is a single stringed instrument, first depicted in paintings in 11th century. Some of the other early single stringed instruments were bow harps, harps, lyres, etc. Kendara rose to popularity in 12th century in Utkala Kingdom in parts of Bihar and in West Bengal.

B. History & Livelihood

The official language in early ages was Sanskrit and it was not understood by most. The musicians used Kendara to link their culture and understanding of it, with the help of the tunes they played which were ancient, mournful tunes. As the instrument developed, ghungroos (small bells) were attached to the bow to enhance the sound. The older kinds of bowed chordophones gave rise to two groups of instruments, the Indian folklore instruments like Kendara, Ektara and the Violins.

Fig. 2. A Jogi with a Kendara

The Jogis continue a tradition by singing ancient religious songs accompanied by playing music on the Kendara. They travel from door to door performing their art and seeking alms, to earn their daily bread. These singers adopt these professions as a family tradition, and it has helped support many families over the ages. Importantly, it has helped these Jogis, who are also musicians to keep the tradition alive. In the early ages and even now, in the remote areas there are limited means of social entertainment. So, through the years, the double coincidence of wants between the Jogis and the listeners of the music enabled them to entertain the people and in return gain alms. Refer Fig. 2.

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C. *History & Livelihood*

The cost of a Kendara normally ranges from 400 to 500 rupees but can be made in a much more cost effectively. The head can be made of a dried coconut shell. The body can be built from a bamboo stick, around 14 inches in length and 0.75 inches wide. A fishing line can be used for a string with a length of 60 inches. A wooden stick can be fashioned as a bow. Ghungroos (small bells) can be attached to bow to enhance sound. Refer Fig. 3.

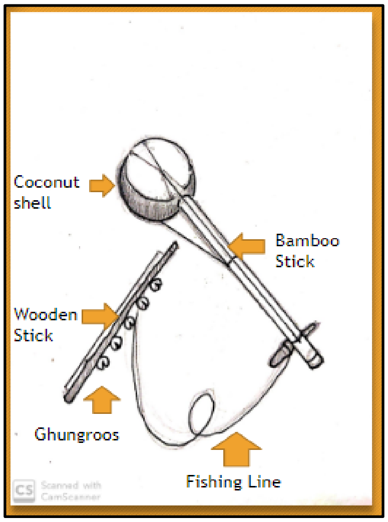

Fig. 3. A cost effective Kendara built with natural objects

D. *Physics Behind the Kendara*

Useful features of string instruments result from usage of bows. Bowing maintains rich harmonic waves. Loudness is dependent on the amplitude of the vibrations and is adjusted by the presence of a hatchet head on the bow, which distributes more weight, and higher force. The action of the bow which drives the strings is a regular cycle of stick-slip-stick-slip, caused by the friction between the two surfaces.

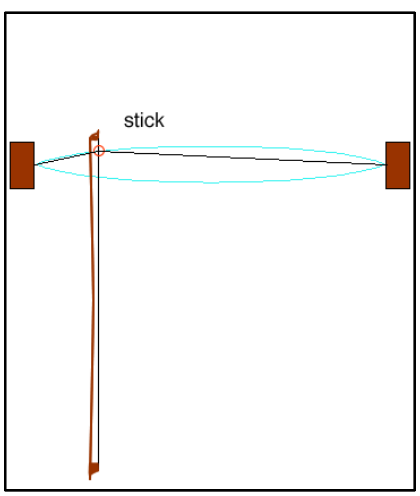

Fig. 4. Helmholtz motion of string due to stick drawn

Usually, the vibration of the string governs the cycle of stick-slip: while the vibration is in the same direction as the bow travel, it sticks and moves with it, when it reverses it slips [1]. This makes the time period of the stick and slip motion the same as that of the vibration of string. Refer Fig. 4.

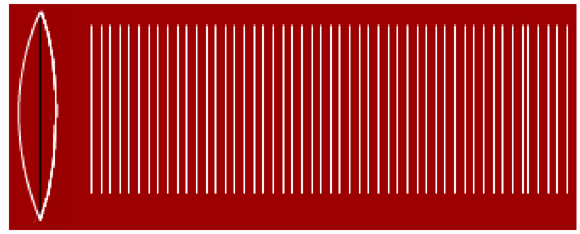

Fig. 5. Longitudinal sound waves

In this way, as the bow slides across the string, a stick and slip motion, as well as the vibration of the string occurs, causing longitudinal sound waves to be produced, as shown in figure. These sound waves hit the head of the Kendara and get reflected in all directions. When they hit a membrane like our ear, a sound can be heard. Refer fig. 5.

E. *Music is Math*

Let us look at the dimensions of Kendara. Refer Fig. 6
Length – 50cm
Width – 15cm
Height of the hemispherical gourd – 14 cm
Weight of the body – 250g
Cylindrical handle – gives a better grip
Hemispherical head – Good resonance of sound

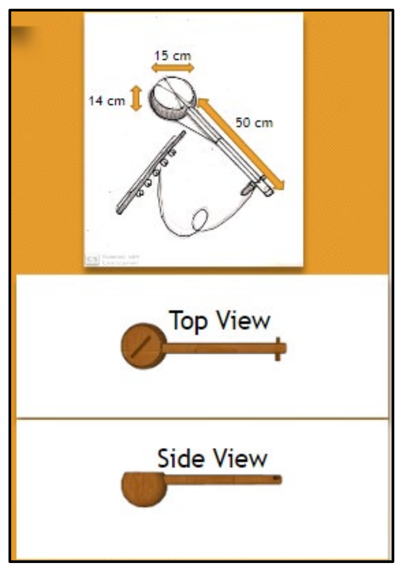

Fig. 6. Physical dimensions of the Kendara

When the bow moves across the string, the string vibrates, and the vibration generates a wavelength.

An Infinite number of vibrations divides the string into an ever-increasing number of equal wavelengths, as shown in column ‘String Vibrations’. These vibrations are similar to the fractions in mathematics. The sequence of frequencies of harmonic scale forms an arithmetic progression. We can say that in column ‘Frequency’, first term is 55, with common difference of 55. Refer Fig. 8.

Note	Frequency	Harmonic	String Vibrations	Fraction of String Vibration
low low low A	55 Hz	Fundamental		1
low low A	110 Hz	Second		1/2
low E	165 Hz	Third		1/3
low A	220 Hz	Fourth		1/4
Middle C	275 Hz	Fifth		1/5
Middle E	330 Hz	Sixth		1/6

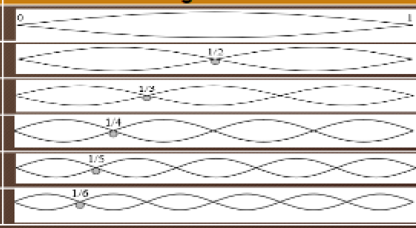

Fig. 8. Arithmetic progression of frequencies for various notes [9]

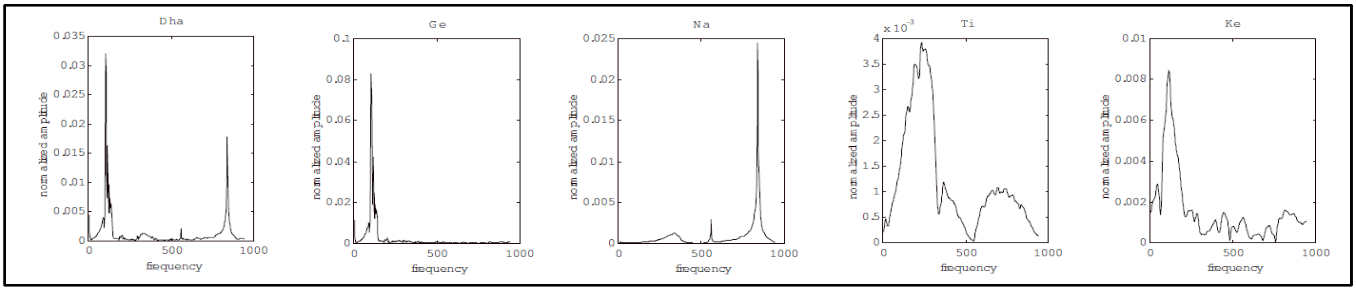

Fig. 9. Frequency graphs of few 'bols' of the Tabla [8]

F. Tabla is all Math and Physics too

The tabla consists of two sealed membranes with leather heads: the smaller "daya" or 'tabla' is played with the right hand, and the larger "bayan" (bass drum) is played with the left hand. Each drum surface is divided into regions as shown in the figure. The 'daya' or 'tabla' is about 15 centimeters (~6 in) in diameter and 25 centimeters (~10 in) high. The 'bayan' is a bit bigger about 20 centimeters (~8 in) in diameter and 25 centimeters (~10 in) in height. Refer Fig. 7.

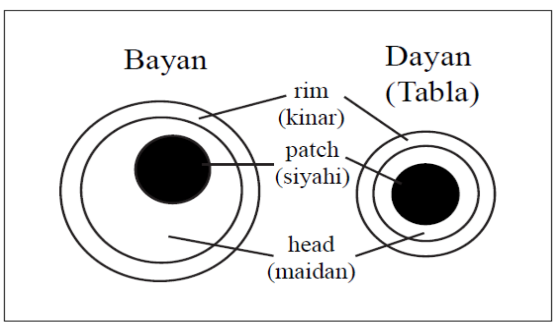

Fig. 7. The percussion instrument Tabla

Table 1
Frequencies of few Tabla 'bols'

Bol	Peak Frequency
Dha	125 Hz
Ge	125 Hz
Na	750 Hz
Tun	330 Hz
Ti	250 Hz
Ke	125 Hz

The Tabla strokes are typically inharmonic in nature [7]. The production of harmonics is different for all tablas due to difference in their structure i.e., the resonant chamber. [7]

The typical sound amplitudes of the Tabla under test were in range of 40 to 90 dB. Refer Fig. 9.

3. Conclusion

This paper presented an integrating studies related to the ancient musical instrument of Kendara.

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