EXPERIMENTS TO FIND CHARACTERISTIC OF THE SOUND IN A DRUM

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ABSTRACT

The problem states that, when dropping a metal ball on a rubber membrane stretched over a plastic cup, a sound can be heard. As the experiment represents, the metal ball on a specific membrane with a specific elasticity, starts going up and down which after a while will stop. Following the membrane deformation and an overview of theories, a model is designed with ANSYS to obtain graphs as tension and strain over time. Number of collisions for each ball, frequency of the sound, the difference between the stretched mode and the normal version of membrane are investigated by Tracker, MATLAB and Besel equation.

Keywords : *Sound, Bouncing membrane, Characteristics*

1. Introduction

The problem states that, when dropping a metal ball on a rubber membrane stretched over a plastic cup, a sound can be heard therefore to find the origin of this sound and explore how its characteristics depend on relevant parameters some experiments are done. As the experiment represents, dropping a metal ball on a membrane with a specific elasticity, causes it starts going up and down on membrane and the speed of the movement will slowly starts to decrease and after a while, the ball will stop on the membrane (Fig. 1 & 2). The frequency of the sound is tracked to find different relevant parameters.

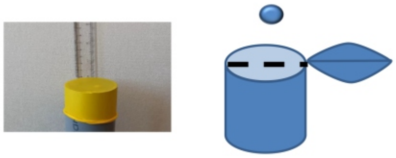


Fig.1: The ball movement on the membrane

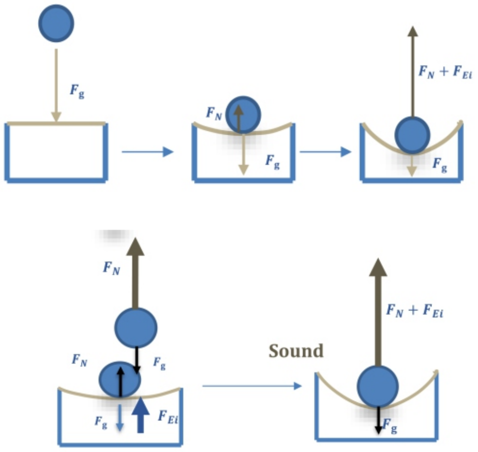


Fig. 2: Free- body diagram of bouncing of the ball on membrane and producing the sound

2. Materials and Methods

Following the membrane deformation and an overview of theories, a model is designed with ANSYS to obtain two graphs known as tension and strain over time (Fig. 3).

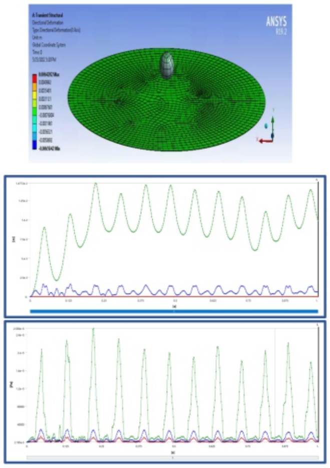


Fig 3. Tension and strain over time by ANSYS modeling

Applied forces to the system are studied to clarify the origin of the sound. Before the ball hits the membrane, there is a gravitational force and by releasing the ball, the potential energy starts to decrease. When the ball goes up again due to the elastic deformation and the accumulated energy in the membrane, a sound can be heard which its origin is the air pressure difference.

The wave characteristics in the membrane by hitting the ball are frequency, speed, amplitude, and wavelength. To obtain the frequency , function of Bessel equation is used (Eqs. 1-6).

$$\frac{\partial^2 T}{\partial t^2} = c^2 T k \tag{1}$$

$$T = A\cos(cst) + B\sin(cst) \qquad f = \frac{1}{T} \tag{2}$$

$$f = \frac{cs}{2\pi} \tag{3}$$

$$\rho^2 \frac{\partial^2 R}{\partial \rho^2} + \rho \frac{\partial R}{\partial \rho} + (\rho^2 - n^2)R = 0 \tag{4}$$

$$r^2 \frac{\partial R}{\partial r^2} + r \frac{\partial R}{\partial r} + (s^2 r^2 - n^2)R = 0 \tag{5}$$

$$R = EJ_n(\rho) \tag{6}$$

Now to obtain the coefficient S and then frequency, there is a boundary conditions if the ball hits or bounces on the edge of the cup (Eqs. 7-11).

$$u(a,\theta,t) = 0 \tag{7}$$

$$r = a$$

$$u = RT\Theta \rightarrow R(a) = 0 \tag{8}$$

$$R = EJ_n(sr) \rightarrow J_n(as) = 0 \rightarrow as = \alpha_{nm} \rightarrow S = \frac{\alpha_{nm}}{a} \tag{9}$$

$$u = \sum_{n,m} E_{n,m} J_n\left(\frac{\alpha_{n,m}}{a} r\right)\left(A\cos\left(\frac{C\alpha_{n,m}}{a} t\right) + B\sin\left(\frac{C\alpha_{n,m}}{a} t\right)\right)(C_n\cos(n\theta) \tag{10}$$

$$+ C_n\sin(n\theta))$$

$$f = \frac{c\alpha_{n,m}}{2\pi a} \tag{11}$$

The difference between the normal membrane and the stretched one over the cup is related to the elasticity (ε) as an important characteristic (Eq. 12).

$$\varepsilon = \frac{l_1 - l_0}{l_0} \tag{12}$$

l_0= normal membrane

l_1 =stretched membrane

3. Experiments

The setup consists of three different balls to measure the frequency for different mass and a covered cup with a stretched membrane (Fig. 4). Spectroid,is used to have a visualized site of the movements for the ball therefore when a metal ball starts bouncing on the specific membrane over the cup the frequency and intensity of the sound which is heard changes and the red diagram shows the maximum holder and the natural frequency for the specific elasticity of the membrane.

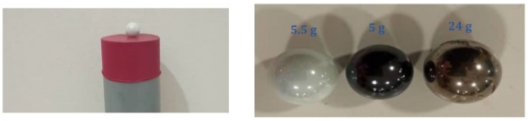


Fig 4. Different balls in our experimental setup

MATLAB is used for the spectrums in each ball at different heights and different elasticities and Tracker to count the number of collisions for each ball and the thump hearing sound that is possible to be recognized by the given diagram for x versus time (Fig.5).

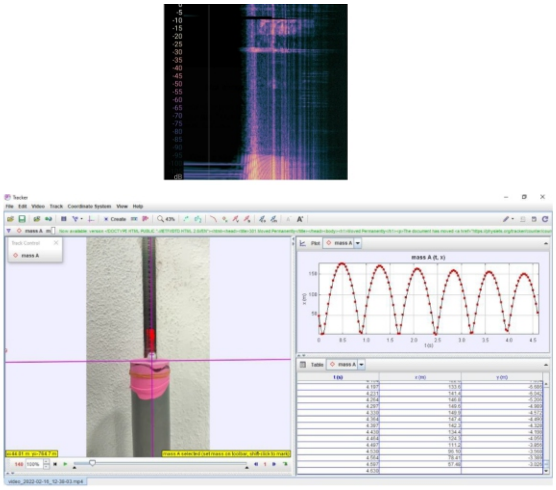


Fig. 5: Frequency vs change of elasticity (ε)

Membrane with different tensions (ε=0.71-3) are used in our experiment to analyze the data related to the number of collisions, frequency and amplitude.

There are three different sounds, which originate from the movements of the ball on the membrane, the cup itself and lastly the surroundings. However, as the theory, the main sound we hear is the sound from the movements of the ball (the max point in spectroid diagram) (Fig. 6).

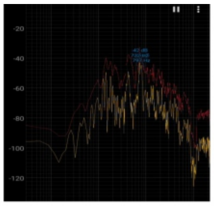
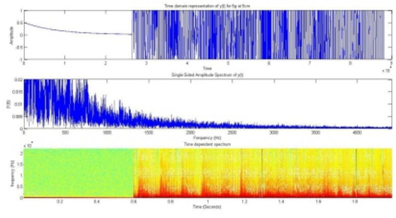


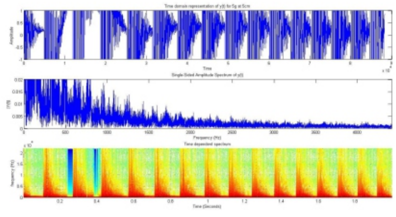
Fig. 6: Spectroid diagram

4. Results

Three different diagrams are analyzed, amplitude verses time, amplitude verses frequency and frequency versus time for three different balls but in constant membrane and height of releasing. It is observed that the most fluctuations are in the period of 500 Hz to1000 Hz (Fig.7).



5 gram at 5 cm – 1 layer membrane



5 gram at 5 cm – 2 layer membrane

Fig. 7: Amplitude verses time, amplitude verses frequency and frequency versus time for three different balls

The average range of frequency in each different tensions, that starts with 0.7 and ends up to 3 shows the least frequency would be the one for ε=0.71 and as much as the epsilon is increasing it is possible to observe an increasing trend of frequency (Fig. 8).

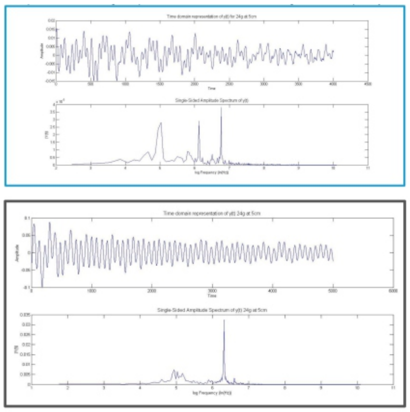


Fig. 8: The average range of frequency in each different tensions

By increasing the distance between ball and membrane, number of collisions will increase (Fig. 9).

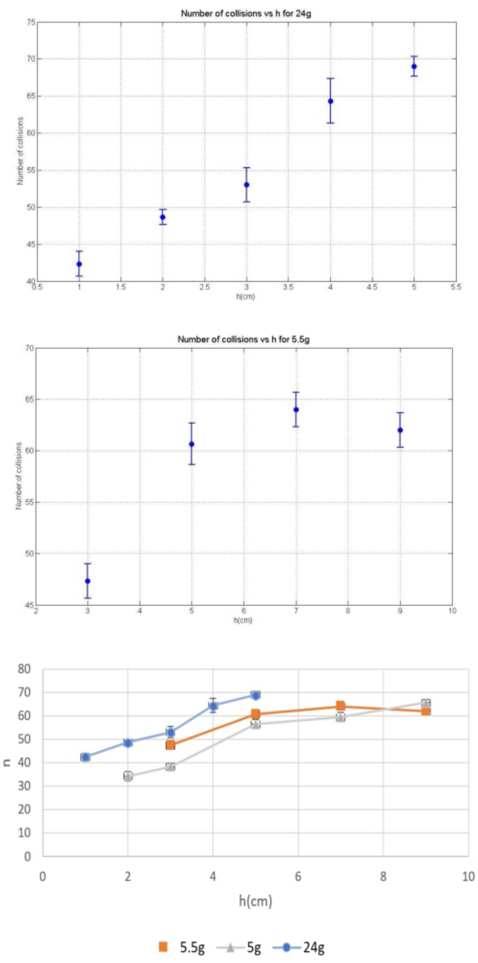


Fig. 9: Number of collisions in different heights and comparing with different masses of balls

5. Discussions

We assumed that by changing the weight and distance between membrane and ball the frequency shouldn't change, and the plots of frequency versus distance and weight, in different weights (5 g to 24 g) proves that the frequency in each distance is almost constant and is a straight line which is a good agreement with the theory (Fig.10).

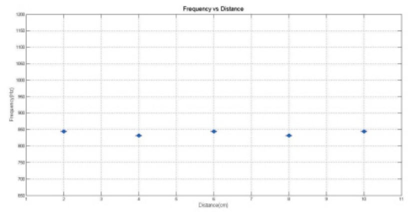
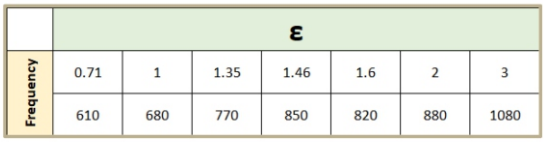


Fig. 10: Frequency versus distance

It is the same for the amplitude of the sound but in different tensions the frequency will change too but the amplitude will be constant. It is observed the change of the amplitude is very small because of the errors in the experiment and surrounding voice.

It can be reported that experimental result and the theory of frequency of the sound have a good agreement with each other (Table 1). We observed a schematic and a real version of the setup and how the system works, and for the experiment we tried different layers of membrane, with latex balloon and a Nitrile rubber material, aluminized plastic and rubber for the toy balloon and different balls (5-5.5-24 g).

Table 1: The average frequency based on the graph for changes of the ε



	ε						
Frequency	0.71	1	1.35	1.46	1.6	2	3
	610	680	770	850	820	880	1080

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