SIREN

[a]Reza Niamanesh, [b]Nita Jafarzadeh

a) rniamanesh@gmail.com, b) nita1385@gmail.com

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http://www.ayimi.org ,info@ayimi.org

ABSTRACT

The problem states If you direct an air flow onto a rotating disk with holes, a sound may be heard. Explain this phenomenon and investigate, how the sound characteristics depend on the relevant parameters. In this research several experiments by different discs are investigated and the data are collected from the recorded sounds.

Keywords : *Siren, Disc, Recorded Sound*

1. Introduction

When we direct an air flow through the hole on the disk, we hear a sound which's a non-periodic wave (Fig. 1). The changes of Amplitude by time are shown on this chart for a disk with 12 holes on it.

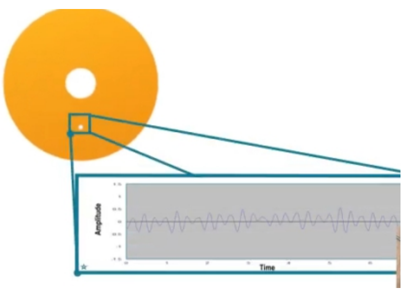


Fig.1: The amplitude of the sound hearing from the disk (Schematic)

The reason behind this phenomenon is the pressure difference that's created. In other words the spinning disk with holes is creating the frequency that we want(Fig. 2). The hole lets the air flow through it and then blocks it periodically and we can control this frequency by changing parameters, that is explained in experiment part.

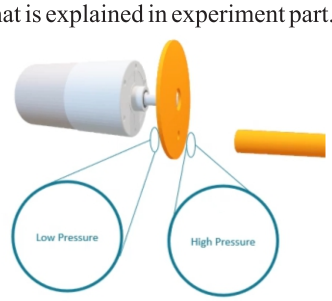


Fig.2: Pressure difference in this phenomenon

By investigating this pressure difference, we realize that pressure difference is versed and what explains is, the Bernoulli principle.

The pressure on the rotating disk and the sound on it is compared with a speaker (Fig. 3).

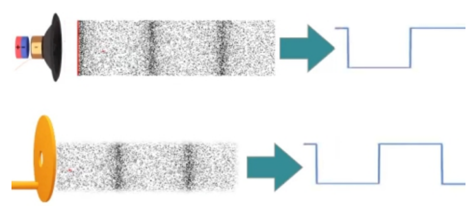


Fig.3: Disk and speaker comparison

Due to the air particles compression, we understood that these two sounds have a similar pattern and so, we can say that they have the same characteristics.

2. Theory

One of the main parameters is frequency. Our theory states: that the frequency is equal to the "number of the holes that are from the same distance around the center" times RPS (Fig. 4).

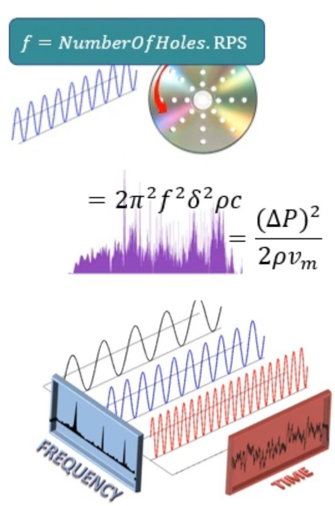


Fig. 4: Frequency vs Time

The next main parameter is the sound intensity and the last parameter is duration that in our situation and experiments is the same so it is not investigated.

To analyze the hearing sound , we need something that can divide the sound into individual frequency components so that we can recognize the siren's frequency and analyze it which is the Fourier series. By using the Fourier series, we can define any function as a sum of sine and cosine functions and by writing this we can recognize the frequency of the siren through intensity (Fig. 5).

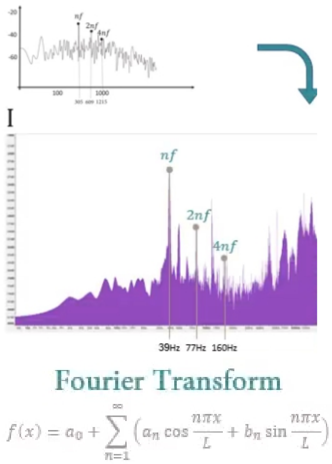
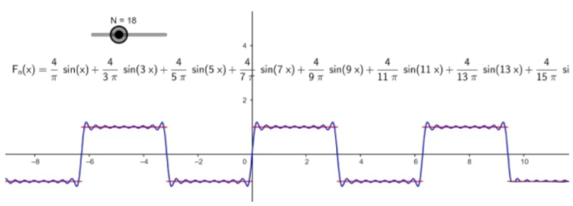


Fig. 5: Fourier series

To understand how Fourier series can define functions, a square function is described by Fourier series here. The higher the value of N, the closer this gets to the desired function.

The sound intensity is one of the main parameters as follows:



The related parameters are defined as :

$$I \propto \begin{cases} f = \text{Frequency of sound wave,} \\ \delta = \text{Amplitude of sound wave} \\ \rho = \text{Density of medium in which sound is traveling} \\ c = \text{Speed of sound} \end{cases}$$

The second formula that we have for sound intensity is relevant to "P" which is "change in pressure", density and the speed of observed sound and that originates from the first formula.

$$I = 2\pi^2 f^2 \delta^2 \rho c$$

$$\rho_{air} = \frac{PM}{RT} \begin{cases} \rho\text{: air density } (\frac{kg}{m^3}) \\ \text{P: pressure (Pa)} \\ \text{R: gas constant} \simeq 8.3\ (\frac{J}{K.m}) \\ \text{M: molar mass of dry air} \simeq 0.029\ (\frac{kg}{mol}) \\ \text{T: temperature (K)} \end{cases}$$

$$I \propto \begin{cases} P = \text{Change in pressure} \\ \rho = \textit{Density of the material the sound is traveling through} \\ v_m = \text{Speed of observed sound} \end{cases}$$

3. Experiments

Our first setup was too basic so, - We improved it by adding a pop filter and a pressure gauge - And we added an air compressor to stabilize the pressure of our set up and also to have tried the experiment with the air compressor. - And finally our last set up was accompanied by a platform with a shock absorber and a fixed distance of the microphone and the airflow holder (Fig. 6).

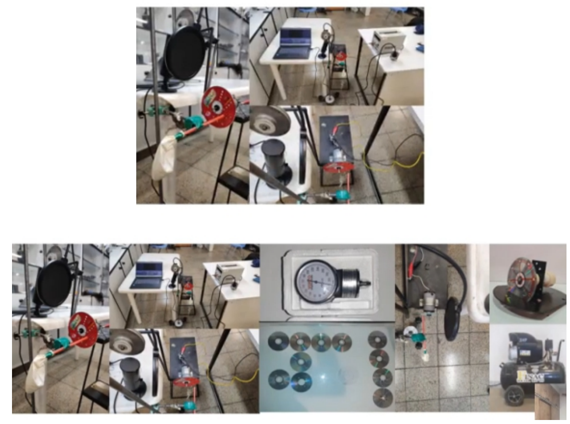


Fig. 6: Experimental Setup

One of the problems that we faced was choosing the airflow for our experiments. First, we thought of blowing, then we thought of using a balloon, and lastly an air compressor. So, we decided to choose between them and we must create a table which include the required features.

As it is observed in the table the compressor would have been a good choice for our experiments but the pressure drop that it has would've had a negative effect on our results so we decided to use the balloon and in order to make sure of the balloon's stability we had to consider pressure difference too (Table 1).

Table 1: The best choice in experimental setup

Option\Ability	Controlling	measurement	Stability
Air Compressor	✓	✓	✓
Balloon	✗	✓	✓
Blowing	✓	✗	✗

By experimenting this 5 times we found that between the time period of 100 to 300 seconds, pressure is approximately constant and so that is the time period we used for the rest of our experiments. Our main airflow that we used for most of experiment was the balloon although on occasion we used the compressor to calculate the effects of pressure .

So by using adobe audition and audacity, we made the siren's frequency bold and reduced the noises.

For better understanding let's compare the frequencies before and after reducing the noise. As shown in the highlighted area other frequencies have been reduced and this chart shows the frequency by time(Fig. 7).

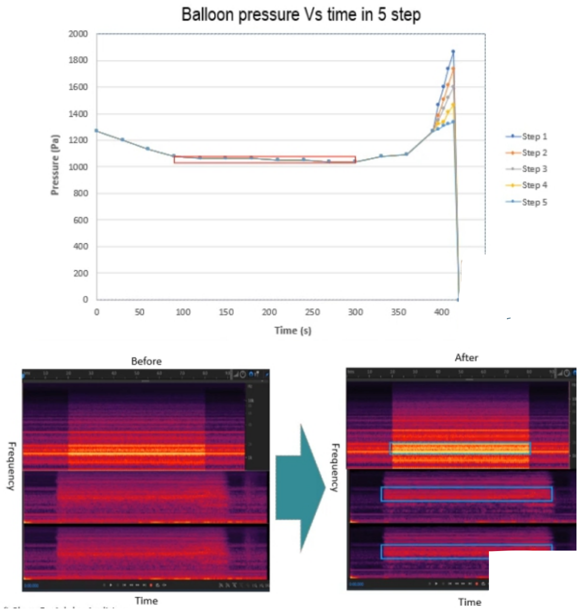


Fig. 7: Frequency in different steps

The first parameter that we experimented was different RPS's which we used 4 different RPS's in our experiments. The sound was the siren's sound with the RPS that is written in front of each frequency (Fig. 8). By dividing the frequency that we hear by RPS, the number that we get is approximately equal to the number of the holes on the disk and by repeating the same experiment with 6 other RPS's and 5 other disks with 5 different hole numbers, we arrive at the same conclusion.

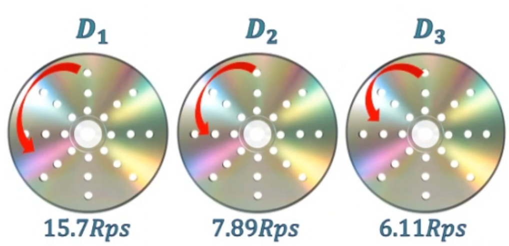


Fig. 8: the RPS of each frequency

So, we can say that the frequency that's produced by the siren is equal to the number of holes that are from the same distance from the center of the disk multiplied by RPS. The rest of the parameters affect the RPS and change the frequency (Table 2) and (Fig. 9).

Table 2: The frequency that's produced by the siren is equal to the number of holes

Disk Num	RPS	Frequency	Voices	
D1	15.7	252.496 Hz	Voice 1	D1
D2	7.9	126.24 Hz	Voice 2	D2
D3	6.1	97.76 Hz	Voice 3	D3

Frequency/RPS		Number of Holes	
252.496 / 15.7	16.0825	16	D1
126.24 / 7.9	15.9797	16	D2
97.76 / 6.1	16	16	D3

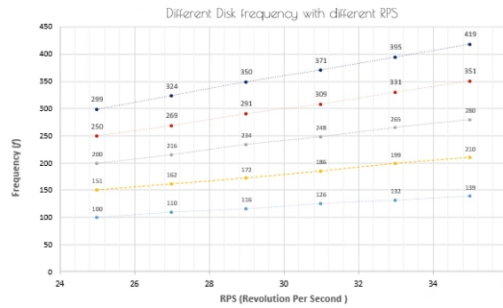


Fig. 9: Different frequencies

"Different pressures" it is the next parameter that was experimented, which due to the Bernoulli they are covered by the experiments with different air flow velocities which we did by using the compressor (Fig. 10).

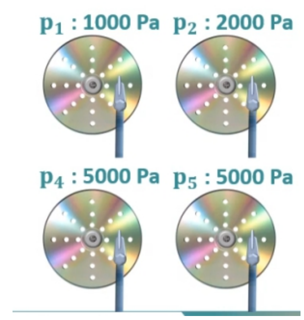


Fig. 10: Experiment in different pressures

As it is observed (Fig. 11) there is a noticeable difference between the numbers extracted from our theory and the numbers that we got from our experiments, this is because of the pressure drop that we mentioned when we chose our airflow and that in all cases I_0 is equal to 10 powered by 7 because our application's I_0.

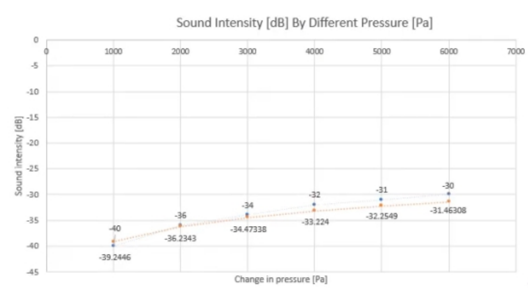


Fig. 11: Sound intensity in different pressures

Due to our experiments the frequency is constant and changes in sound intensity can be calculated with this form

$$f_1 = f_2 = f_3$$
$$I_1 < I_2 < I_3$$
$$\rightarrow \quad I = \frac{(\Delta P)^2}{2\rho v_m}$$

P = change in pressure
ρ = density of the material the sound is traveling through
v_m = speed of observed sound

Next parameter is the material of the disk which we experimented with ply wood and a CD. It was observed the frequency and the sound intensity in both is approximately equal because in this case the thickness and all the hole sizes were constant, and within the disk standards, the mass didn't change much and nor did the RPS and frequency, and so we can say that the material of the disk doesn't make much of a difference in the phenomenon in this case (Fig. 12).

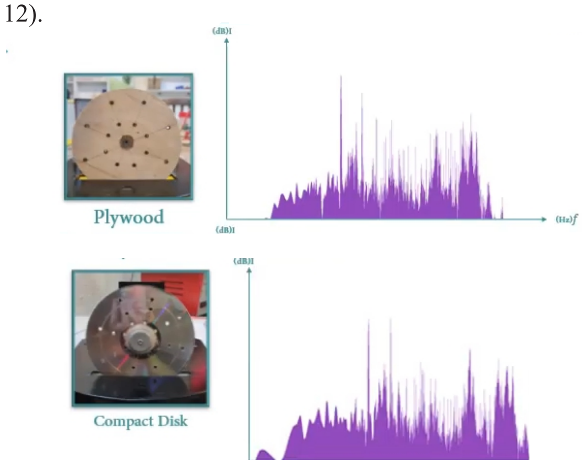


Fig. 12: Comparing two different materials

Next parameter that we investigated was the thickness of the disk. By increasing the thickness of the disk the mass of the disk increases, and from that, the RPS decreases and we expect a thicker disk to have a lower frequency and with a lower frequency according to our theory we have a lower sound intensity and so we can say that with increasing the thickness of the disk both frequency and sound intensity decrease (Fig 13).

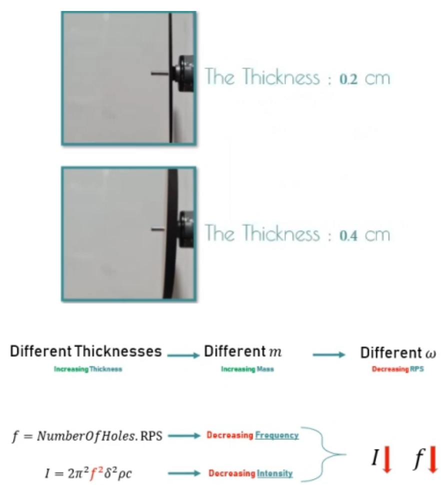
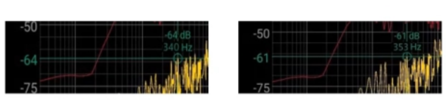


Fig. 13: Different frequencies in diffferent thicknesses

In figure (14) the results of our experiments for 4 thicknesses of 0.2,0.3,0.4 and 0.5 centimeters are shown. By putting all the frequencies together, we realize that by increasing the thickness of the disk, it's frequency and consequently the sound's intensity decrease.



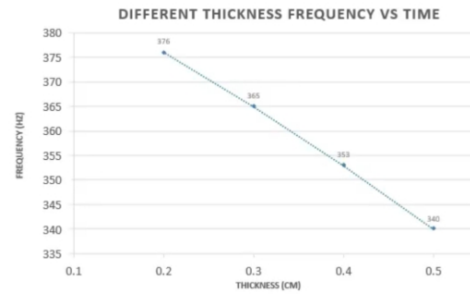


Fig. 14: Frequency VS time in different thicknesses

The next parameter that we investigated is the angle of the drill bit. we did the experiment with a vertical angle and an oblique one. It was found that if we experiment with angles other than oblique and vertical the sound intensity decreases and the frequency stays constant (Fig. 15).

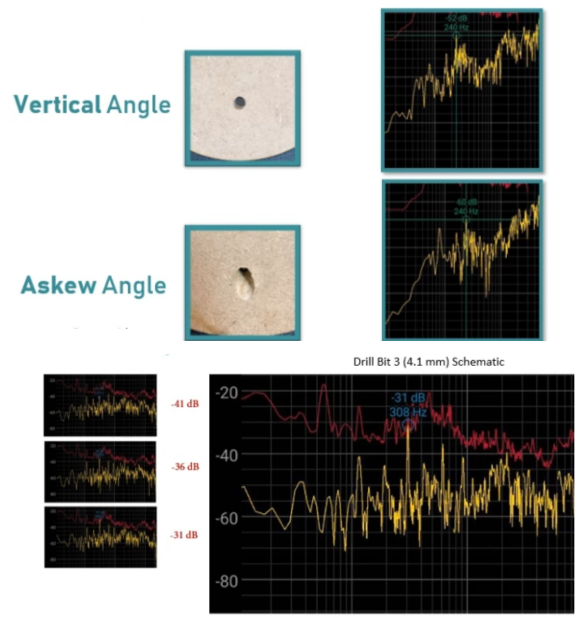


Fig. 15: Different angles

The last parameter that we experimented was different sizes of holes on the disk as it is observed this is the first drill bit which is 1.9mm (Fig. 16).

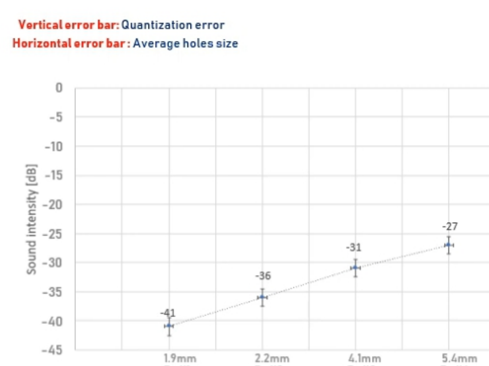


Fig. 16: Different sizes of the holes

The plot for a 2.2 mm drill bit shows only the sound intensity has increased by changing the size of the hole.

By combining the 4-drill bit plots we realize that by increasing the diameter of the holes sound intensity increases but frequency stays constant.

Here we created a melody by directing the airflow to different rows of holes on the disk .

4. Conclusion

This is a summary of all the experiments that we did:

- With the increase of RPS and the number of holes the frequency increases
- The increase of pressure results in the increase of the sound's intensity
- Changes in the material of the disk is negligible
- The increase of the disk's thickness decreases the frequency
- The increase of the hole's diameter increases the sound intensity
- The increase of the number of the holes increases the frequency
- We conclude that the speaker and the siren have similarities and then we investigated the sound characteristics.

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