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A swirling vortex of colorful fluids

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FREEZING DROPLET

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ABSTRACT

If water droplets drip onto a very cold metal surface, they freeze quickly, but during the freezing process, the shape of the water droplets changes and they often become sharp, frozen droplets. This phenomenon is caused by the expansion of water during freezing and surface tension, which causes the droplet to grow taller each time it freezes in a conical shape as the volume in the upper layer of the drop increases. In this article, we will try to investigate the effect of surface tension and other parameters on this process by conducting a series of experiments.

Keywords : *Water droplet, freezing, cone shape, surface tension*

1. Introduction

One of the unusual properties of water is its freezing from the surface. According to the laws of thermodynamics, when water molecules freeze, their density becomes lower than that of liquid molecules, so they move upwards and accumulate at the surface of the liquid. In this phenomenon, when a drop of water hits a metal plate, it starts to freeze from the surface where it hits the metal. This is because at the moment the drop hits the metal surface, due to the very high temperature difference between the metal and the drop, the molecules are deprived of the opportunity to move and the drop freezes from the surface where it hits the metal. When the drop hits the metal surface, an ice shell forms and grows upwards and progresses along the contact surface. The molecules inside the liquid volume are pulled in all directions and the resultant force on them is zero, but the molecules on the liquid surface are pulled in only one direction by the liquid molecules and the attraction force in the other direction and beyond the liquid boundary that is in the vicinity of the air and is introduced by the air molecules is less, hence the progress of the freezing process around the droplet is faster than inside the droplet, so that the liquid and unfrozen part above the droplet takes the form of a round and spherical cap. Based on the exceptional properties of water, this fluid expands when freezing. However, since in this phenomenon the water does not expand in the radial direction and expands vertically, the expansion is concentrated on the tip of the droplet and finally the combination of the two factors of expansion and the restriction caused by surface tension causes the tip of the droplet to tilt upwards.

After the formation of the cone shape of the droplet tip, the gradient or concentration change of water vapor around the tip increases. Water vapor spreads around the tip, like an electric charge that is attracted to the tip of a lightning rod, and during the condensation process (preferably) freezes on the tip of the droplet. In this article, we try to examine the parameters and factors affecting this phenomenon with some experiments and to explain and prove the cause of its occurrence more clearly (Fig. 1).

As we know, the freezing of a drop is also a function of the pressure and temperature of the surrounding environment; changing the temperature and air pressure around the drop affects the formation of the phenomenon and leads to different results, therefore, in all experiments, the pressure and temperature of the surrounding air, as well as the humidity level, are constant .

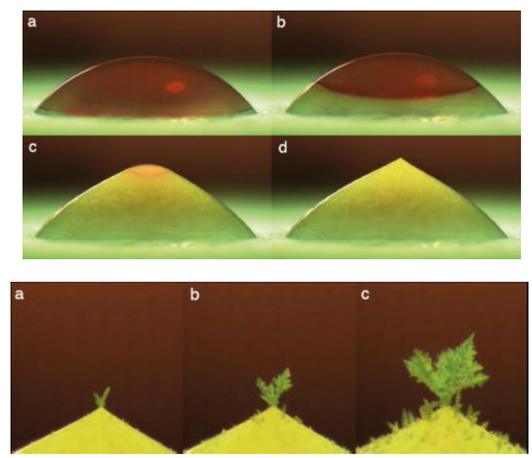

Fig. 1: The geometry of the water droplet

Another parameter whose change may affect the results of the experiments but is taken constant is the volume of the drop. 1 It is clear that the temperature of the water drop also has a significant effect on its formation, and the lower the temperature of the drop, the faster it freezes. The temperature of the drop in all experiments was 20 ° C and there was no change in it (Fig. 2).

Fig. 2: The hygrometer shows a constant number during the tests.

2. Theory

We need to know if the gravity influences on this Problem or not.

When water droplet is freezing, the radius of the spherical cap is decreasing and water is expanding upward (Fig. 3).

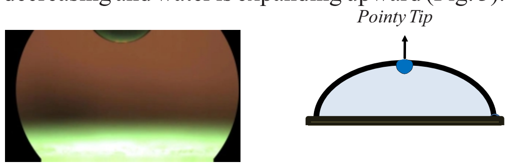

Fig. 3: The shape of water droplet

Droplet radius is too small and the Bond Number is given by:

$$Bond\ Number = \frac{\rho g R^2}{\gamma}$$

which in our experiment its range is: 0.25 – 0.4

As our assumptions :

1-Plate Temperature= T_0

2-The surface is Parabola shape

3-The Sum of θ and θ' is Constant and the surface propagates along θ.

4-The solidification front is planner .

5-The freezing process is directed along the water–vapor interface .

Philippe burnt assumed :

- The solidification front is planner .
- The freezing process is directed along the water–vapor interface (Fig. 4).

$$Tan\theta \frac{dR}{dZ} = -1$$

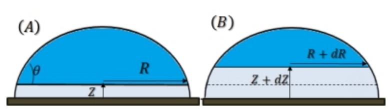

Fig. 4: Philippe burnt assumption

The geometry of the water droplet is explained as follows (Fig. 5):

$$Tan\theta = -\frac{\Delta h}{\Delta R} = -\frac{dZ}{dR} - \frac{dA}{dZ}\frac{dZ}{dR}R^2 - 2RA\frac{dR}{dZ}\frac{dZ}{dR}$$

$$Tan\theta\frac{dR}{dZ} = -\frac{\Delta h}{\Delta R}\frac{dR}{dZ} = -\left(1 + R^2\frac{dA}{Dz} + 2RA\frac{dR}{dZ}\right)$$

$$Tan\theta\frac{dR}{dZ} = -1 \underbrace{- R^2\frac{dA}{Dz} - 2RA\frac{dR}{dZ}}_{\text{The difference}}$$

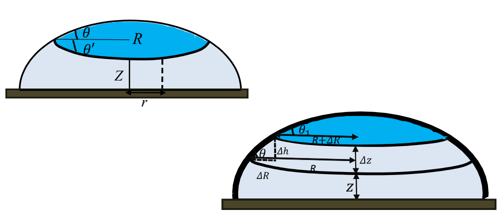

Fig. 5: The geometry of the water droplet

2.1. Mass Conservation

D.M Anderson and Philippe burnt assumed :The solidification front is planner (Fig. 6).

$$\rho_l\, dV_l = -\rho_s\, dV_s$$

$$\frac{\pi}{3}R^3\left(\frac{3Sin\theta - 3Cos^2\theta\ Sin\theta}{Sin^3\theta} - 3Cos\theta\left(\frac{2 - 3Cos\theta + Cos^3\theta}{Sin^4\theta}\right)\right) = -\frac{\rho_s}{\rho_l}\pi R^2 dZ$$

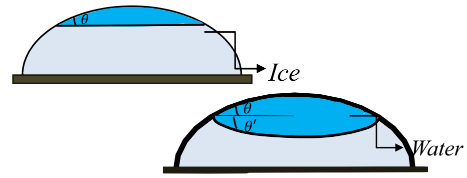

Fig. 6: Solidification shape

$$V_l = V_{sc} + V_{concave}$$

$$\rho_l\, dV_l = -\rho_s\, dV_s$$

$$\frac{\pi}{2}R^4\frac{dA}{dZ} + 2\pi A\frac{dR}{dZ} + \pi R^2\left(\frac{2 - 3Cos\theta + Cos^3\theta}{Sin^3\theta}\right)$$
$$+\frac{\pi}{3}R^3\left(\frac{3Sin\theta - 3Cos^2\theta\ Sin\theta}{Sin^3\theta} - 3Cos\theta\left(\frac{2 - 3Cos\theta + Cos^3\theta}{Sin^4\theta}\right)\right)$$
$$= -\frac{\rho_s}{\rho_l}\left(\pi R^2 + \pi\frac{R^4}{2}\frac{dA}{dZ}\right)dZ$$

and the contact angle:

$$\theta + \theta' = Constant$$

$$\frac{d\theta}{dz} + \frac{d\theta'}{dz} = 0$$

3 Differential Equation

$$\begin{cases} \theta + \theta' = Constant \\ \rho_l\, dV_l = -\rho_s\, dV_s \\ \frac{1}{Tan\theta} = -\frac{\Delta h}{\Delta R}. \end{cases}$$

→ Mathematica

By using equations :

- $\theta + \theta' = Constant$
- $\rho_l\, dV_l = -\rho_s\, dV_s$
- $\frac{1}{Tan\theta} = -\frac{\Delta h}{\Delta R}.$

and initial condition:

- $R_0 = 0.001m$
- $\theta = 120° = \frac{2}{3}\pi$

we can plot the radius of the droplet during freezing (Fig.7).

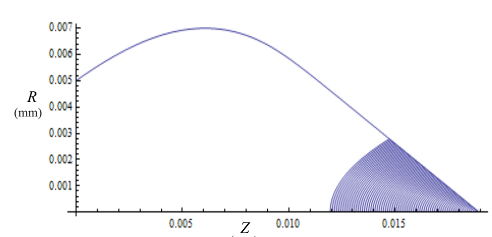

Fig. 7: The radius of water droplet Vs height

3. Experimental Setup

By taking photo in different steps the shape of the water droplet in different times during freezing is captured. Test equipment : Dropper, Metals frozen to minus 20°C, Detergent, thermometer, hygrometer, pressure gauge (Fig. 8).

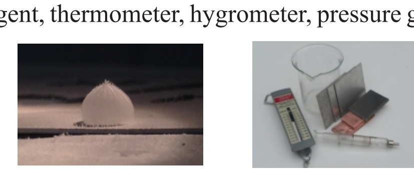

Fig. 8: Photo taken in our experiment

3.1. Experiment No. 1

In this experiment we are going to investigate the difference in the material of the plate and its purpose is to demonstrate the importance of the heat capacity of the object in the freezing of the drop. In the design of the experiment, we first cover all three types of metals (iron, copper, and aluminum) with plastic and cloth bags to protect the metals from moisture and reduce the percentage of error in the experiment. Then, we cool them to a temperature of minus 20 degrees and place a drop of water on them. It is observed that the drop on the aluminum phase, which has a higher heat capacity than iron and copper metals, freezes faster and its tip becomes conical (Fig. 9).

Fig. 9: The conical shape on the aluminum phase

3.2. Experiment No. 2

Another parameter that is effective in freezing the drop is the mass of the metal plate, and it is obvious that the greater the mass of the plate, the greater its capacity to absorb heat and the faster the heat transfer between the drop and the metal. In this experiment, we tried to observe the effect of changing the mass of the plate on the freezing process of the drop. The design of the experiment is similar to the previous experiment, with the difference that here, instead of three types of metal, one type of metal with different masses was used. As expected, the drop froze faster on the metal piece that had the greater mass.

So increasing the mass of the plate can improve the freezing process (Fig. 10).

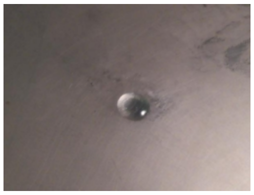

Fig. 10: The conical shape by increasing the mass of the plate

3.3. Experiment No. 3

To prove the importance of the surface tension of water in the occurrence of the phenomenon, based on the fact that impurities reduce the surface tension, an experiment was designed in which three different percentages of impurities were used and the results were analyzed and examined. Instead of pouring pure water, we used a mixture of water and detergent. Given that the molecule of this type of detergent has a polar (hydrophilic) end and a non-polar (hydrophobic) end; and on the other hand, the water molecule is also a polar molecule, as a result, the water molecule attracts the polar parts of the detergent and creates adhesion. By releasing this droplet, which is accompanied by impurities, on a metal plate whose temperature has been lowered to 20 degrees Celsius below zero, changes occurred in the freezing process of the droplet. In the first stage, a mixture of water and 8% impurities was used1 and the result was almost similar to pure water and the droplet froze and its tip became conical. In the second stage, 14% impurities were used and it was observed that the droplet froze but its tip did not become conical. In the third stage, 50% impurities were used and, as expected, a droplet formed on the metal and did not freeze.

So the evidence shows that surface tension plays a fundamental role in the formation of the phenomenon and its absence prevents the phenomenon from occurring, and the lower the percentage of water purity, the lower the probability of freezing the drop (Fig. 11).

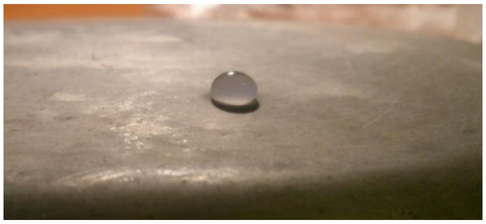

Fig. 11: The surface tension plays a fundamental role in the formation of the phenomenon

4.2. Experiment No. 4

The way the drop is placed can also affect whether it freezes or not, as well as the formation of a conical tip. The purpose of designing this experiment is to investigate how to place the drop on the screen and freeze it. In this experiment, all parameters are constant and only the drop is dropped from different distances on the screen. It is obvious that the further the drop is placed from the screen, the greater its gravitational potential energy, and when it hits the screen, it has more energy and breaks up. When the initial height of the drop is reduced, it was observed that the drop spreads out when it hits the surface on the screen, as a result it freezes, but its tip does not become conical. Therefore, it is better to place the drop from a lower height and near the surface on the screen, because if we drop the drop from a higher height, the desired result will not be obtained.

4. Conclusion

In the process of freezing a drop on a cold metal, if the temperature and mass of the drop and the metal, the way the drop is placed on the surface, and other parameters such as the drop temperature, viscosity, drop volume, ambient air pressure, ambient temperature and the water drop, and the specific heat capacity of the metal and water are appropriate and the phenomenon is formed; it is observed that the ice shell that forms from the contact surface of the drop with the metal advances upwards, and the water expands vertically and the tip of the drop becomes conical. As we observed in experiment number three, if we reduce the surface tension by increasing the impurity, the cohesion decreases and eventually the drop loses its drop shape and does not freeze naturally.

References

[1] http://phys.org/news/2012-10-droplets-sharp-ice -peaks.html

[2] Physics Halliday

CANDLE LIGHT TRICK

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ABSTRACT

It is possible to relight a candle that has just been blown out by lighting the smoke that is created in the process. Indeed, the smoke contains vaporized wax which is the substance that burns in the flame in the first place. What is the maximum distance (between the match and the candle) from which one can relight the candle? Identify the important parameters and find how they influence the maximum distance.

Keywords : *Candle light, Smoke, Maximum distance*

1. Introduction

First, let us estimate the origin of the phenomenon observed. When you light a candle, lot happens (Fig. 1)! Heat melts wax close to the wick and the melted wax flows up the wick by capillary action. The wax is vaporized (becomes a hot gas) and its hydrocarbons break down into hydrogen (H) and carbon (C). Now gaseous wax burns in oxygen (O) to produce water vapor, carbon dioxide, heat, and light. . For a paraffin candle, the balanced chemical equation is:

$$C_{25}H_{52} + 38\ O_2 \rightarrow 25\ CO_2 + 26\ H_2O$$

Fig. 1: The origin of the phenomenon observed

It's interesting to note that even though water is released, the air often feels dry when a candle or fire is burning. This is because the increase in temperature allows air to hold more water vapor.

The steam is made in the blue part of a candle flame, where the wax burns cleanly with lots of oxygen; the smoke is made in the bright, yellow part of the flame, where there isn't enough oxygen for perfect combustion to take place. The smoke is an aerosol. It contains a substance called "soot" which is a black material composed mostly of carbon that comes from burning organic items. (You can see soot on surfaces near or over candles and at the top of glass coverings around them.) Another component of the smoke from a candle is unburned wax vapor. This is the material that causes candle wax to appear white or gray. For a few seconds, its temperature is high enough that it will combust (burn) with the touch of a flame. It rises, of course, because it's hot so you will probably need to be above the wick to light it. The smoke trail is almost straight and you can touch the flame to any part of the trail that is connected to the wick. The wax vapor reignites and the blue flame travels along it to the wick where the candle burning process starts all over.

2. Theoretical Approach to Reach the Maximum Distance

Take a closer look at the steps to create the desired phenomenon:

Fig. 2: A candle consists of a wax cylinder with a wick through the center. The flame melts a pool of wax at the top. Source: https://www.thenakedscientists.com/get-naked/experiments/jumping-flames

Fig. 3: The molten wax is drawn up the wick where it evaporates and then burns with the oxygen in the air. Source:https://www.thenakedscientists.com/get-naked/experiments/jumping-flames

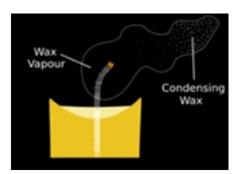


Fig.4: The wax evaporates condensing to form a cloud of smoke. Source: https://www.thenakedscientists.com/get-naked/experiments/jumping-flames

Fig. 5: The vapor is very flammable so you can relight it. Source: https://www.thenakedscientists.com/get-naked/experiments/jumping-flames

There are two main approaches in order to reach the maximum distance (d_{max}) which we can relight the candle:

1. producing smoke as much as possible.
2. Make the smoke trail move in almost linear direction as long as possible.

To achieve these two aims above, there are set of effective parameters divided into two columns:

Table 1: Parameters to achieve d_{max}

CANDLE PARAMETERS	ENVIRONMENTAL PARAMETER
1. wax formulation	1.formulation of the air
2.wax aroma	2.oxygen density
3.wax melting point	3.air humidity percent
4.wick dimension	4.pressure / temperature
5. candle dimension	5.blowing angle
6.flame color	6.blowing power
7. flame height	

we tried to investigate how they influence the d_{max} by theories and doing experiments. Also we used Maxwell-Boltzmann Distribution Function to calculate the most proper time to relight the candle.

3. Maxwell-Boltzmann Distribution Function

$$\frac{dN}{N} = \left(\frac{m}{2\pi k_B T}\right)^{1/2} e^{\frac{-mv^2}{2k_B T}} dv$$

$$f(c) = 4\pi c^2 \left(\frac{m}{2\pi k_B T}\right)^{3/2} e^{\frac{-mc^2}{2k_B T}}$$

$$\frac{df(c)}{dc}\Big|_{C_{mp}} = 0$$

$$C_{mp} = \sqrt{\frac{2RT}{M}}$$

$$C_{avg} = \int_0^{\infty} c f(c) dc = \sqrt{\frac{8RT}{\pi M}}$$

$$C_{rms} = \sqrt{\frac{3RT}{M}}$$

- dN/N is the fraction of molecules moving at velocity v to v + dv,
- -m is the mass of the molecule,
- -kb is the Boltzmann constant, and
- -T is the absolute temperature.1
- -R is the gas constant,
- -T is the absolute temperature and
- -M is the molar mass of the gas.

4. Relevant parameters – according to table (t.1)

Wax:

Candles are made up of one or more wicks surrounded by a solid material, the wax, which can be burnt. Waxes are mainly defined by their physical properties, not their chemical properties. For our purposes, we can think of a wax as a complex mixture of fatty organic chemicals that has wax like properties:

- It has a relatively low melting point above room temperature (50°–90°C) and melts without decomposition above 40°C.
- It has relatively low viscosity just above the melting point.
- It has no viscoelasticity (deforms and gradually returns to shape after a force is applied).
- It can be polished (buffed) and becomes plastic above 20°C with slight pressure.
- It burns with a sooty flame (the characteristic property of a candle).
- It's a poor conductor (of both heat and electricity)

There are several types of wax readily available for making candles today - some natural, some synthetic, some a little bit of both, and each has its own particular 8Wax, Stearin , Microcrystalline wax ,wax, Gels , Paraffin Wax , etc.

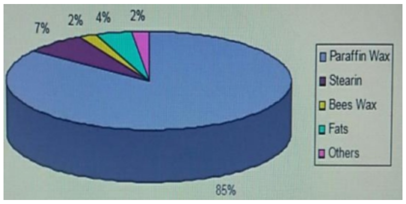


Fig. 6: Share of Raw Materials for Candles
Source: http://candles.org/wp-content/uploads/2014/05/MatthaeiPetereit2004TheQualityCandle.pdf

Paraffin Wax:

Paraffin is the world's most commonly used candle wax. It is composed primarily of straight-chained, saturated hydrocarbons, and is removed from petroleum during the refining process. It is a relatively hard wax and comes in a variety of melting points, which allows it to be used for many different types of candles. Developed in the 1850s, paraffin is valued for its opacity, lack of color, lack of odor and consistent burn qualities.

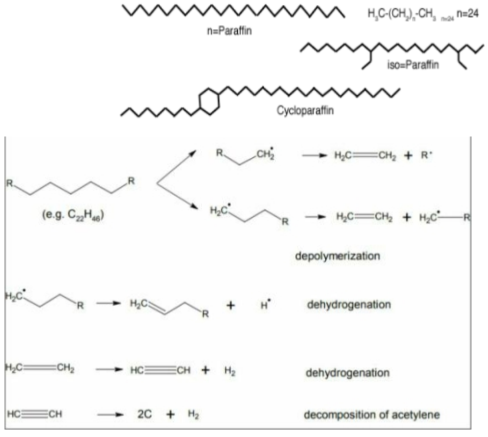


Fig. 7: Paraffin wax = C20-40 H42-82
Source: http://candles.org/wp-content/uploads/2014/05/MatthaeiPetereit2004TheQualityCandle.pdf

Pretty much any type of candle can be made with paraffin wax. The melting point is the primary determinant of the type of candle you can make with it.

- Low melt point paraffin (less than 130F) is used for container candles in jars, cups or glasses
- Medium melt point paraffin (130F-150F) is used for candles that need to stand on their own - votive, pillars, and other molded candles
- High melt point wax (greater than 150F) is used for more special applications like hurricane candle shells, over dipping, and other special candle making applications

Wick:

wick, often referred to as the soul of the candle, plays a central role when regarding candle quality. It has a decisive influence on the burning behavior of the candle and is included in discussions about candle quality especially with regard to its composition and combustion products formed in/by it.

The wick is mainly made up of braided cotton threads which are usually treated with inorganic compositions. Long, fibrous cotton with a uniform structure produces the best results. The fibers have a major influence on capillary action, wick stance and ultimately the ability of the wick to self-trim. The inorganic elements of the wick treatment prevent afterglow of the wick when it is extinguished. The formation of a crystal skeleton after the chemical treatment process increases the stability of the wick.

The strength and number of the fibers as well as the type of braiding (mainly differentiated between flat and round wicks) determine the capillary action and stability of the wick. The curve of the wick in the flame can be influenced by the introduction of special tension or stability threads.

The choice of wick and candle material used, together with the diameter of the candle, must complement each other optimally to ensure the ideal burning of the candle. The wick regulates the melting, absorption, evaporation and burning of the fuel used.

There are many tables which can show us each kind of wicks with their most important properties and applications as well, in order to make choosing process scientifically.

Table 2: Different kinds of wicks with their most important properties

Core Type	Burn Rate
Cotton	2.51- 8.19
Paper	3.03 – 8.65
Zinc	1.65- 7.24

Flame:

When observing a candle flame the following schematic structure can be seen:

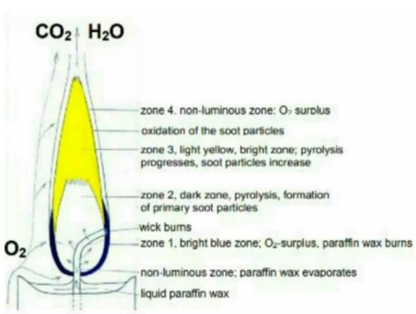
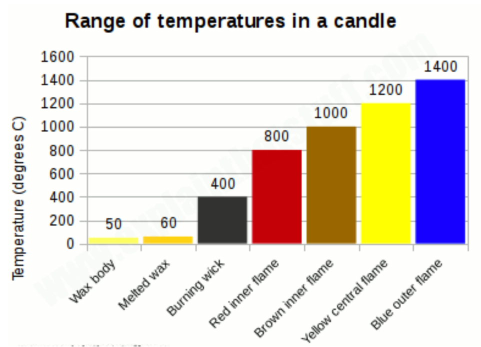


Fig. 8: The structure of a candle flame
Source: http://candles.org/wp-content/uploads/2014/05/MatthaeiPetereit2004TheQualityCandle.pdf

Here are some approximate temperatures for the different parts of a candle and its flame. Note that the exact temperatures vary quite a bit depending on all kinds of different factors, notably the type of wax from which the candle is made but also the ambient (air) temperature, and how much oxygen is present. Please don't take these values as absolutely definitive ones that apply in all cases—they're just a rough guide.

1. Wick: 400°C (750°F).

2. Blue/white outer edge of the flame (and also the blue cone underneath flame where the oxygen enters): 1400°C (2550°F).
3. Yellow central region of the brightest part of the flame: 1200°C (2190°F).
4. Dark brown/red inner part of the flame: 1000°C (1830°F).
5. Red/orange inner part of the flame: 800°C (1470°F).
6. Body of the candle: 40-50°C (104-122°F).
7. Melted pool of wax on top of the candle: 60°C (140°F).



5. "COMSOL" Analysis of Burning Candle

As we are still in the beginning of experimental phase , we used COMSOL analysis of burning candle in order to gather more scientific information to make designing experiments easier and clarify the results we want from them.

- Simplifying Assumptions

Heat of combustion approximated by a simple heat source

Stationary analysis

Symmetric boundary conditions

Source: https://www.comsol.com/paper/download/62922/koppenhoefer2_paper.pdf

- Model set up

Air flow is described by conservation of mass, momentum, and energy.

$$\nabla \cdot (\rho\, \mathbf{u}) = 0$$

$$\rho\, \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \nabla \cdot \left(\eta \left(\nabla \mathbf{u} + (\nabla \mathbf{u})^T \right) - \frac{2}{3} \eta (\nabla \cdot \mathbf{u}) \mathbf{I} \right) + \rho\, \mathbf{g}$$

$$\nabla \cdot (-k \nabla T) = Q - \rho\, c_p \mathbf{u}$$

Conduction in the solid domains:

$$\nabla \cdot (-k \nabla T) = Q$$

Surface heat flux due to radiation:

$$q_r = \varepsilon \left(G_m + F_{amb} \sigma\, T_{amb}^4 - \sigma\, T^4 \right)$$

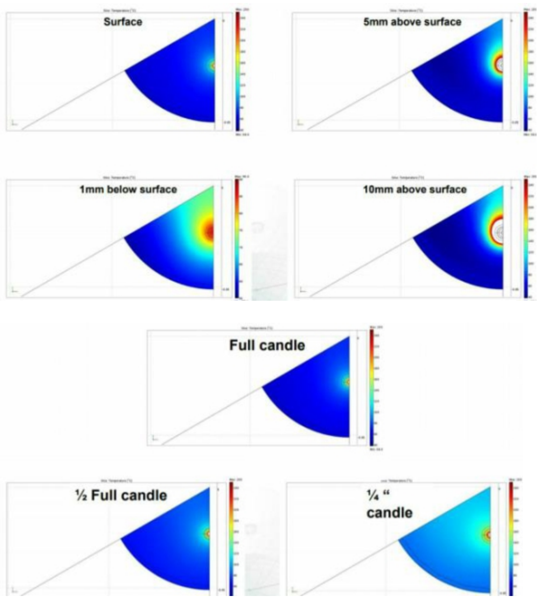
Mutual irradiation (Gm):

$$J = (1 - \varepsilon)\left(G_m + F_{amb} \sigma\, T_{amb}^4 \right) + \varepsilon \sigma\, T^4$$

Heat flux qr is set to zero at the boundary Source term is included in the flame region to account for cooling due to radiation.

6. Results

Temperature at Wax surface:



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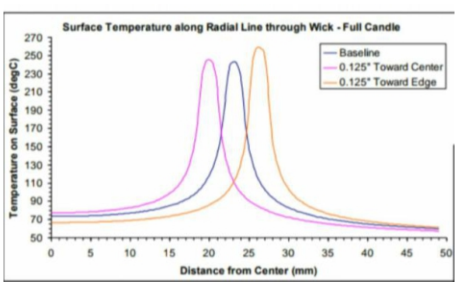
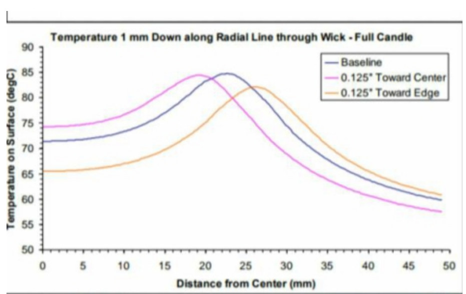
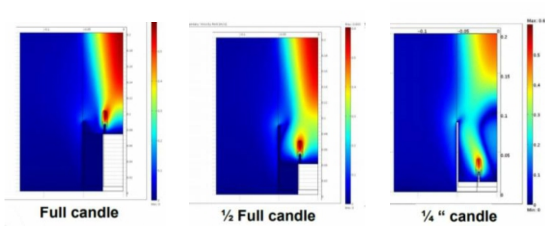
Wick location:





Flow:



7. Experiments

These are the designed experiments we're going to do to investigate important factors on d_{max}.

Important note: recording environmental conditions during all of experiments have to be done.

1 Wax formulation:

use 3 samples of typical waxes (paraffine, stearine, beeswax) with same amount of mass , Do the relighting process on each of them and by repeating this experiment , find the d_{max} for each sample.

Paraffine:A | stearine:B | beeswax:C

- Recording environmental conditions: (including : pressure, temperature , volume of the experiment room, air flow, ...)
- Recording distances (between the match and the candle) from which one can relight the candle
- Averaging of recorded distances
- Considering the errors in the measuring and recording devices and also the experimenter , ...

2 Wax aroma:

Use candles with and without aromas , with different kind of aromas and different densities

Investigate is it effective on the amount of smoke which is created after blowing flame out ?

3 Wick dimension:

Use same kind of wax (it's better to choose best wax by considering the result of 1st experiment) with different dimensions in its wick and investigate how it influence dmax.

- Use wicks with different length
- Use wicks with different cross-section diameter

4 Candle dimension:

Rebuild candles with different dimensions by melting same amount and type of wax.(it's better to choose best wax by considering the result of 1st experiment)

- Use waxes with different length
- Use waxes with different cross-section diameter

5 Flame colour:

Use candles with different flame colours , investigate its effect on this phenomenon.

6 Formulation of the air:

Use a clean room and give it the measured amount of oxygen, nitrogen, carbon dioxide and other gases present in the air, investigate the effect of this factor by making changes in the formulation of the air you gave it.

- Pay attention to all the reactions occurred in the process
- The effect of oxygen density and air humidity percent can be investigated by this approach too.

7. Temperature/ pressure:

Do the same experiments in different temperatures and pressures , investigate the effect of these parameters by recording the d_{max} in each experiment.

- Consider the influence of temperature on wax melting point.

8 Blowing angle / blowing power:

Use a device with can gave you air flows with controllable powers and angles, then investigate the effects of these two parameters and find proper power and angle for blowing the flame out , in order to reach the maximum distance (between the match and the candle) from which one can relight the candle.

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STATIC SPEAKER

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A B S T R A C T

Producing sound in different conditions is conceptually interesting. In the other hand, use of sounds for our objectives are attractive, too. For example, some people think about thermoacoustic engines to make heat with sound and reversely produce heat using of sound. The last has more application for our routine life. Here with the aid of fundamental concept of Physics we were able to produce sound in new way. We use the fourth discovered phase of matter, plasma .

Keywords : *Sound, Plasma, thermoacoustic engines*

1. Introduction

Producing sound in different conditions is conceptually interesting. In the other hand, use of sounds for our objectives are attractive, too. For example, some people think about thermo acoustic engines to make heat with sound and reversely produce heat using of sound. The last has more application for our routine life. Here with the aid of fundamental concept of Physics we were able to produce sound in new way. We use the fourth discovered phase of matter, plasma, as you know, is the quasi-neutral gas shape material that consist of ions with same number of e[illegible]ust satisfy two conditions. One is that in the media there must be a Restoring force that affect the wave fronts. Here compressibility of gas provides it for us and second is the media must have inertia. Inertia refer to property of matter does not enable a body to do anything except oppose such active agents as forces and torques. In fact, the inertia of the ions allow the sound propagate through matter. If there not be inertia, the agents that transport the mechanical wave (sound) will move with the wave and we can`t detect anything. Maybe just some noises. A plasma arc speaker is an improvement on the traditional diaphragm loudspeaker because the driver, electrical arc has very little mass and low inertia, reducing distortion. It is capable of producing very high frequencies due to its ability to move very small quantities of the gas.

The ions in plasma have sound-like Response, however electrons participate in these oscillations. This sound-like behavior named, Ion Acoustic Wave.

2. Related reports, technologies or devices

1. One of the interesting works on this area is Graphene Speaker. For the aid of producing sound, they flow current through Graphene. To produce sound, the grapheme layer is rapidly heated and cooled, which in turn causes the surrounding air to expand and contract, creating sound waves. By strategically controlling the alternating electrical current flowing through the Graphene, the scientists also found they can mix frequencies together, and even amplify or equalize specific sounds. Which means the amp, EQ, and towering speakers that make up most home stereos might one day be replaced by a single, solid-state device.

2. A cone less, no-moving-parts dynamic speaker has its internal components firmly locked within a plastic housing structure to prevent their movement relative to the housing. During operation of the speaker, mechanical sound energy that it creates is transmitted through the walls and ceiling of the room to provide an expanded sound generation pattern. The internal components of the speaker include a voice coil internally anchored to a wall of the housing, an annular magnet member sandwiched between and fixedly secured to first and second annular metal washer members, and a metal alignment shaft having one end closely received in the core portion of the voice coil, and an opposite, radially enlarged end press-fitted into one of the washers and forming with the side surface of the central magnet member opening a reverberation chamber which is closely adjacent the voice coil but does not physically receive the coil. In an alternate embodiment of the speaker the housing is foreshortened in a manner exposing the magnet member and the washer member into which the radially enlarged end portion of the alignment shaft is press-fitted.

3. Another amazing device is Controlled Resonance Technology. It does not use conventional drivers to reproduce sound.CRT on the other hand uses a soundboard much like a musical instrument to reproduce sound. The soundboard uses resonances to generate sound-wave. By generating resonance originating from multiple locations on the board. A board frequency range can be generated within very small fluctuations in amplitude.

4. As an idea in our objective is producing sound by strong electromagnet that change its polarity and then push and pull the charged gas that surrounded the electromagnet. Finally alternating of polarity of electromagnet will produce pressure waves or roughly speaking, sound.

3. Aims and methodology

As was explained in abstract, we use plasma for producing sound. Plasma has two different type named Warm plasma and Cold plasma. Here we use cold arc plasma. The temperature of electron in such plasma can reach about 3ev (1ev ~ 11600 k) then the "cold" refers to ions and ambient neutral species.

Plasma can be created with arc discharge in The Gas. Arc regime is third discharge regime after Glow discharge and Corona discharge. When the high-voltage power supply applied between two electrodes, first corona regime that is ionizing of atoms near high voltage probes so combination of electrons and ions will appear and with increasing the discharge current, those two region get together that basically create region of the gas that`s basically full of electrons and ions that named "plasma". It essentially become a conductor and goes too huge current between two probes. This is called an arc discharge.

Since the plasma was made of Electrical Arc, it is important to mention plasma arcs have a major advantage. They have no resonance or transient problem. Most audiophiles know that the lighter the material used in a speaker, the faster the response can be, and the better transient they produce. Plasma speaker, works by moving air via changing the temperature in its chamber. A plasma speaker uses an electrical arc to ionize and compress the air around it to play music, all with no moving parts! Actually plasma arc loud speaker has a better frequency response far exceeding the material of speaker cones.

It`s so important to say that the speed of sound in plasma is bigger than its speed in air. Another advantage about plasma is the speed of electron with considering motionless ions is much bigger than propagation speed of sound and subsequently, we don`t face with resonance of sound wave and it causes to be any noises on played music and we detect frequencies of played music sharply in the contrary of ordinary speakers. Meanwhile for many purposes, the conductivity of a plasma may be treated as infinite.

Starting with simplified one-fluid equations with considering a field-free uniform plasma ($E0 = B0 = P0 = V0 = 0$) of hot electrons and cold ions and then considering small perturbation in density and velocity about steady state with linearization and simplifying and providing third equation that is poisson`s equation we reach to dispersion relation for plasma and with solving $\epsilon(\omega) = 0$, propagation modes will be found.

$$\partial_t(n_{i,e}) + \partial_x(n_{i,e} V_{i,e}) = 0$$

$$\partial_t(V_{i,e}) + V_{i,e}(\partial_x(V_{i,e})) = - q_{i,e}/m_{i,e}(\partial_x(\phi))$$

$$\partial_{xx}(\phi) = -4\pi e(n_i - n_e)$$

With the approximation $n_e = n_i$ and $V.\nabla V = 0$, these reduce to the one-fluid equation.
Small harmonic perturbations are:

$$n_\alpha = n_{\alpha 0} + \hat{n}_{\alpha 1}(x)e^{-i\omega t}$$

$$V_\alpha = \hat{V}_{\alpha 1}(x)e^{-i\omega t}$$

$$E = \hat{E}_1(x)e^{-i\omega t}$$

$$B = \hat{B}_1(x)e^{-i\omega t}$$

So the continuity equation for the perturbed density and velocity is :

$$i\omega n_{i1} - in_0 K \cdot V_{i1} = 0$$

$$i\omega n_{e1} - in_0 K \cdot V_{e1} = 0$$

The momentum transport equation for the perturbed quantities, including electron pressure, is :

$$-i\omega V_{i1} = e/m_i E_1$$

$$-i\omega V_{e1} = e/m_e E_1 + (iK\gamma p_0/n_0 m_e)(n_{e1}/n_0)$$

Where γ is the intrinsic feature of the gas that here for air is equal to 1.
Poisson`s equation provide a third relation between n_1, V_1 and E_1.

$$iK.E_1 = -4\pi e(n_i - n_e)$$

Eliminating V between Eq.5 and Eq.6 and then substituting n_{i1} and n_{e1} from state equation for ideal gases ($p = nk_BT$) into Eq.(7) gives this result :

$$(1 - (\omega_{pi}/\omega)^2 - (\omega_{pe}/\omega)^2(1/(1-(K^2/\omega^2)(\gamma k_B T_e/m_e)))) K \cdot E_1 = 0$$

A reasonable choice of γ might be $\gamma = 1$ from isothermal processes. From equivalent dielectric constant for a plasma of warm electrons and cold ions is :

$$\epsilon = (1 - (\omega_{pi}/\omega)^2 - (\omega_{pe}/\omega)^2(1/(1-(K^2/\omega^2)(\gamma k_B T_e/m_e))))$$

Instead of using Poisson`s equation, Eqs. (5) and (6) can be combined with Maxwell`s equation:

$$\nabla \times \mathbf{B} = (4\pi \mathbf{J}/c) + (1/c)\,\partial_t(E)$$

To give

$$\nabla \times \mathbf{B}_1 = -i\omega\epsilon E_1$$

Now K dotted into Eq.(9) yields to Eq.(7), singling out the electrostatic waves ($B_1 = 0$).
In addition, Eq.(9) includes electromagnetic waves ($K.E_1 = 0$, a wave with its electric field perpendicular to its direction of propagation.)
So dispersion relations become:

$$\omega^2 = \omega_p^2 + (k_BT_e/m_e)K^2$$

$$\omega = \omega_p(1+k_BT_e/m_e\omega_p^2K^2)$$

$$\omega = K((k_BT_e/m_i)^{1/2} / (1+k^2\lambda_{De}^2)^{1/2}$$

where:

$$\lambda_{De} = k_BT_e/4\pi ne^2$$

The dispersion relation is still valid only for long-wavelength disturbances, i.e,for $K^2(k_BT_e/m_e) << \omega_p 2$ (equivalent to $K^2 \lambda_{De}^2 << 1$), so the sound wave propagate with the speed:

$$\partial_K(\omega) \approx C_s = (k_BT_e/m_i)^{1/2} << (k_BT_e/m_e)^{1/2}$$

And is less than the electron thermal speed. It`s necessary to mention that our assumption ($\gamma = 1$,propagation of sound in plasma is isothermal processes) is valid because the electrons moves faster than the wave fronts or, roughly speaking, the ions and so they dose not sense any change in their surrounding temperature. It means that propagation of sound in plasma pass an isothermal process.

4. Experiments and Results

Setup was constructed from a high-voltage power supply, a pulse generator and two electrodes. Pulse generator provide our arbitrary music with coupled frequencies and put it on plasma via high-voltage power supply (Fig. 1).

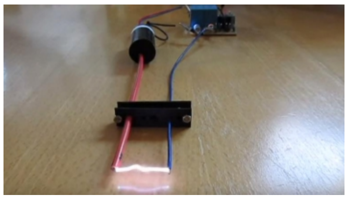

Fig. 1: Experimental Setup

In the below there is comparison of "Amplitude – Impulse Response (Frequency Response)" plots between two different speakers. As you see the Plasma speaker (left plot) enjoy a clear and noiseless impulse response. While in the RealTek HD speaker (right plot) the frequencies did not detect sharply and there is a lot of noises in output sound (Fig.2) .

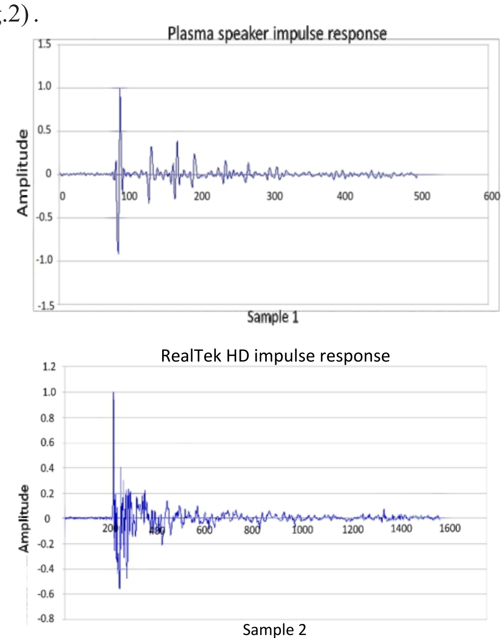

Fig. 2: comparison of "Amplitude – Impulse Response (Frequency Response)" plots between two different speakers

A plasma arc speaker was made and its operation was studied. By use of the plasma speaker we have attempted to study the phenomenon of electric discharge through the ionization of air molecules.

The plasma speaker has unparalleled performance and fidelity in the higher ranges. The unique nature of its "massless" driver gives it very low coloration. As a specialized tweeter it may do very well in combination with a subwoofer. Low frequencies are naturally less directional than high frequencies, so a conventional subwoofer in combination with a plasma tweeter could theoretically show an even frequency response.

*This analysis belong to Sylvan Zheng.

An interactive report on the acoustical qualities of a plasma loudspeaker

Plasma Speaker Experiment | Princeton Plasma Physics Lab

MAGNETIC HILLS

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ARTICLE INFO

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ABSTRACT

A small amount of a ferrofluid placed in an inhomogeneous magnetic field forms hill-like structures. Magnetic Ferrofluids (MFFs) are colloidal suspensions made up of tiny ferromagnetic particles, about 10nm in diameter, suspended in a carrier liquid and have magnetic and liquid properties simultaneously. Ferrofluid surface is exposed to a heterogeneous magnetic field which instead of being flat or curved, it is a convex surface or nails-like protrusion. In this research we are going to investigate how the properties of these structures depend on relevant parameters.

Keywords : Ferrofluids- colloidal solution - heterogeneous magnetic field- Magnetic Peaks

1. Introduction

Magnetic Ferrofluids (MFFs) are colloidal suspensions made up of tiny ferromagnetic particles, about 10nm in diameter, suspended in a carrier liquid and have magnetic and liquid properties simultaneously. Ferrofluid surface is exposed to a heterogeneous magnetic field which instead of being flat or curved, it is a convex surface or nails-like protrusion. Its reason is applying of too much magnetic forces which causes the interaction between surface forces. It should be noted that ferrofluids are liquid in normal states but solid when approaching a magnet (http://nanoclub.ir).

2. Definitions Regarding Different Parameters

Magnetic field: is the medium of the influence of two charges and is generated by moving electrical charges. When there is a moving charged particle, a magnetic field is generated in its surrounding.

Every magnetic field has the lines called magnetic field lines (David Halliday, Robert Resnick, Kenneth Crane, 2002, page 199). The direction of moving of the lines are in clockwise direction, "coming out" of the North Pole of a magnet and "going into" the South Pole of a magnet.

When you pour some iron powder on a paper near a magnet , the iron powder immediately form the magnetic field lines. This shows the magnetic field around the magnet .

Ferrofluids : Ferromagnetics are the materials which are attracted and form in the same direction if placed against a magnetic field. In other words, its magnetic dipoles are aligned.

Ferromagnetics are divided into two categories: hard ferromagnetics and soft ferromagnetics. Soft ferromagnetics are the materials that are easily converted to magnet and easily lose their magnetism characteristic. Hard ferromagnetics are the materials that are hardly converted to magnet and hardly lose their magnetism characteristic (http://edu.nano.ir).

Ferrofluid is a liquid that is attracted to the poles of a magnet. It is a colloidal liquid made of nanoscale ferromagnetic or ferromagnetic particles in a carrier fluid.

Pole and pole density: Magnetic poles that are the two ends of the magnet, which have more magnetism rather than other parts of the magnet. If you divide a magnet into smaller pieces, again there will be the two N and S poles calling them the magnetic dipole. The density of magnetic field lines are more in magnet ends wherever the density of magnetic field lines are more, the attraction and repulsion is stronger (www.chap.sch.i).

The more the number of magnetic field lines per unit area, the more the density of the pole. Pole density can be the power of attraction and magnetic field. The more closer to the poles, the more the pole density will be and the more closer to the middle ground between the two poles, the less pole density will be.

Magnetism is a phenomenon that is occurred on the surface; therefore magnetism is a surface phenomenon, not a volumetric one. It should be noted that the densification of poles occurs on magnet surfaces.

Surfactant: The particles dispersed in ferrofluid are Colloidal, but after a short time they get together and form larger particles. The smaller the particles are, the better the solution exhibits magnetic properties. That is why materials called surfactants are added to the solution which prevents the particles from joining together and particles lose their magnetism over the time (www.rasekhoon.net). It should be noted that the surfactants reduce the surface tension and the surface material is active. The surface active molecule should be partially hydrophilic and lipophilic (www.britannica.com).

3. Experimental Setup

Ferrofluid Recipe:

1) Prepare 10.77 grams of developer (Fig. 1)
2) Prepare 1/8 cup or 16 grams of toner (Fig. 2)
3) Prepare 19.84 grams of oil (Fig. 3)
4) Mix the ingredients and density of ferrofluid:1.86 (Fig. 4)

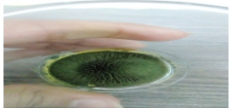


Fig. 1: Developer

Fig. 2: Toner

Fig. 3: Oil

Fig. 4: Mixing result

4. Determination of Ferrofluids Formation

1) A full Ferrofluid never precipitate.
2) Ferrofluids have hexagonal structure; because hexagons cause all the surface be involved and causes the clusters be formed. If the surface is in another form, all the surface will not be involved, leading to not creation of bulges.

Examined materials for Ferrofluid creation:

1) Developer + water
2) iron powder + castor oil
3) Developer + oil (preferably vegetable)
4) developer + Acetone
5) developer + Children's Body Oil
6) developer + oil
7) developer + Petrol
8) developer + Toner + Oil
9) Cassette + Acetone + oil

5. Reason of Magnetic Peaks Formation

The main reason for Formation of magnetic peaks, is magnetic field lines; the magnetic peaks are the magnetic field lines that are displayed in three dimensions. The more the magnetic field lines are, the more the peaks with higher altitudes will be generated.

In addition, the height and number of them depends on magnet strength, the magnetic field lines, and pole density. It should be noted that the bigger the magnet is, the more the number of generated peaks and the greater their height. Each of the generated clusters are small magnet themselves that if we approach a magnet, they will be attracted.

6. Surveyed parameters

1) Change in the container level

Small surface: 4 cm (about 50 clusters). (Approximate height of the highest cluster: 1.27 mm)

Vast surface: 9 cm (about 150 clusters). (Approximate height of the highest cluster: 1.55 mm)

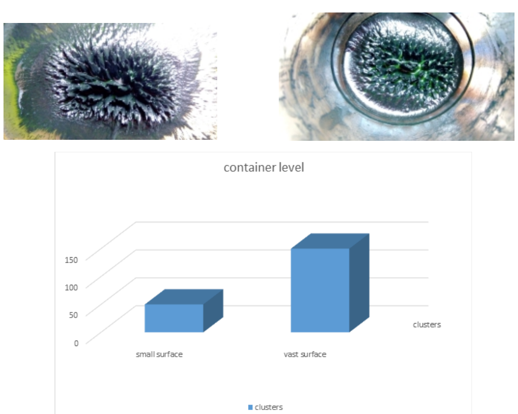


Fig. 5: The clusters in two different vessels

2. Change in thickness of Ferrofluid container

Cellophane thickness: 0.02 mm (almost 150 clusters). (Almost height of the highest cluster: 1.70 mm)

Glass thickness: 5.16 mm (almost 300 clusters). (Almost height of the highest cluster: 1.38 mm)

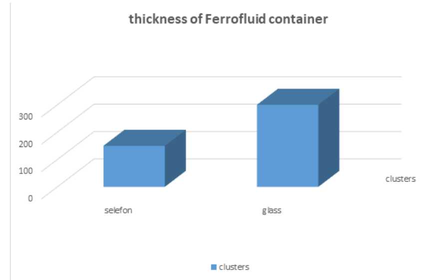


Fig. 6: The clusters in two different Ferrofluid container

3. Size of the magnet

Big magnet: 4 cm (almost 400 clusters). (Almost height of the highest cluster: 5.2 mm)

Small magnet: 1.5 cm (almost 20 clusters). (Almost height of the highest cluster: 2.3 mm)

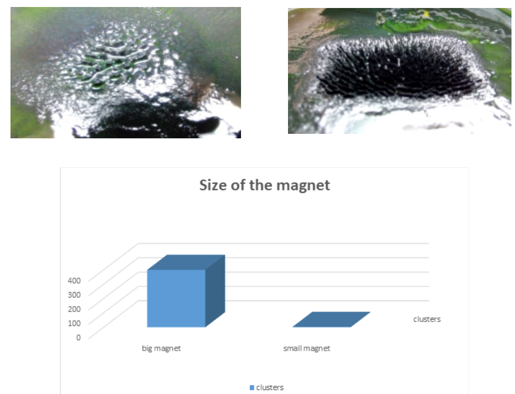


Fig. 7: The clusters with two different size of magnet

4. Change in Ferrofluid temperature

32°C : (almost 100 clusters). (Almost height of the highest cluster: 1.9 mm)

-4°C : (almost 300 clusters). (Almost height of the highest cluster: 2.1 mm)

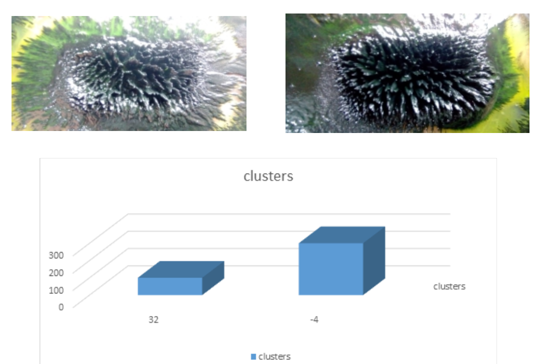
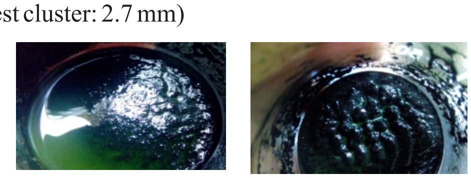


Fig. 8: The clusters in two different temperatures

5. Change in volume of Ferrofluid

High volume: 25 ml (Almost 10 clusters). (Height negligible)

Low volume: 12.5 ml (Almost 30 clusters). (Height of the highest cluster: 2.7 mm)



6) Type and size of the constituent particles

The more nanometer particles, the better magnetic properties the Ferrofluids will have.

7) Concentration of Ferrofluids

Ferrofluids concentration is very important, because if the concentration is too high, less peaks are generated and the less the concentration of Ferrofluid, the more peaks and the more their height.

8) Pole density and magnetic field lines

The more the density of the pole, the more the number of magnetic field lines; consequently the more the number of peaks and their heights.

9) Amount of surfactant

The amount and type of surfactant in Ferrofluids has great importance. Surveyed: soap, shampoo, dishwashing liquids, etc.

10) Ferrofluids Color Change

Ferrofluids color depends on the constitutive magnetic particles color; For example toner Ferrofluid is black; developer Ferrofluid color is green; cobalt Ferrofluid is blue, and copper Ferrofluid is red. It should be noted that particles change in Nano-scale.

7. Conclusion

The more the surface of Ferrofluids, the more peaks will be generated, but there will be not such change in their height and the more the thickness of the container, the more peaks with sharper tips and lower heights will be generated. The larger the magnet is, the more peaks with higher heights will be. As the temperature of Ferrofluid increases, with approaching a magnet to the Ferrofluid, peaks are generated easier and faster than the ones in low temperature but the number of peaks and their heights are lower than the ones in cold temperatures, and the peaks have sharp tips in negative temperatures. The larger the volume of the Ferrofluid, the less clusters with lower heights will be and the lower volume, the more clusters with higher heights will be.

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CANDLE LIGHTING TRICK

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A B S T R A C T

Indeed, in this essay we are searching for finding an explanation to our problem. Why we can relight a candle from upside by a little distance of candle's top part? Actually we have some probable solutions for solving this problem. Some solutions are focused on paraffin part of candle. Some are focused on hot air that existed around candle. And other ones are which that we try to solve it by theories that insist on external elements which can effect on phenomenon.

Keywords : *Candle, Paraffin, Hot air, Lighting*

1. Introduction

Indeed, in this essay we are searching for finding an explanation to our problem. Really why we can relight a candle from upside by a little distance of candle's top part?

Actually we have some probable solutions for solving this problem. Some solutions are focused on paraffin part of candle. Some are focused on hot air that existed around candle. And other ones are which that we try to solve it by theories that insist on external elements which can effect on phenomenon.

First approach is made of theory that says relighting of candle is the cause of that evaporated paraffin and some fine particles of paraffin wax ; existed in around air of candle due to flame heat , so they will be alight by approximating a burning object to them.

Another one approach is based on heated air that existed around of candle, above it. Actually this insist on that the burning air reaches to the top of candle by effect of Archimedes' law that causes moving of fluid materials by their density. And then, burning air will relight candle.

And then the last theory is made of checking external elements that could effect on phenomenon and by checking them, we can talk about some explanations that are about burning source of fire and some other such as this.

For gaining a logical theory and reach to a strong solution which could win other explanations, we are forced to construct some tests. Our experiments are searching for testing our theories. Some are for testing that this phenomenon are because of paraffin or heated around air.

And some other ones are for testing that have any external elements, any important effect on this phenomenon. For reaching the answer we will construct some tests and will study results.

At the end we will study results and will construct a strong logical theory for solution and then study our solution's scientific features.

2. Related Reports, Technologies or Devices

By a simple search on internet, we will face to many fantastic results. For this phenomenon there is no important experiment that its aim be focused on gaining a scientific explanation for it. And also there is no scientific essay in scientific search engines. For this problem there are some homemade experiments that are done by people, are recorded into video tapes and can be found on YouTube enough. These videos are recorded sometimes by experts and are under controlled laboratory conditions.

Actually we need to search for some key words by search engines and we will have some experiments with related results which their laboratory conditions are acceptable; of course under some determined limits.

In their experiments ; in almost more of them, the basic approach is about finding a way for relighting of candle, but without straight contact between candle burning part and a burning source of fire such as match. Then we can understand that there is a logical relation between burning source and top part of candle that burns, which can transfers enough heat to top part of candle in order to lighten it.

In almost all of them the only thing that is under studying, is the base of phenomenon and other aspects of phenomenon have not been tested in experiments.

Some fantastic and useful experiments are shown in footnote. It is good for reaching a scientific and logical explanation of phenomenon that see these videos online.

3. The Aims and Methodology

The same explained in previous section of essay, we mentioned that did not exist any strong and scientific approach and experiment that in it we could study every logical and scientific aspects of phenomenon. By the time there are no test could exam different theories that exists about explaining phenomenon.

We know that human mind logical perception always chooses some choices between others that they have needed adaptations to its limits. By this, we know that our choices will be limited by approaches which are about relations of relighting and three important factor.

Our method for testing these theories is experimentalism. Actually it determined by its many exams to test a theory. Theory could passes successful test or fails it.

Indeed we gain a totally and finally result based on limited observations that we could had through experiments. And those result which we named it a true theory, is just a theory that is not in contrast with any experiment which we done up to now.

It does not mean yet that it is a logical base or a natural law.

We know that in laboratory for testing an elements and its effect on phenomenon we must fix any effective element in the experiment and then change one which is our purpose to be tested. Then we will gain some results that its changes is based on determined element. We can lighten a simple candle in a room with closed doors and windows _ due to air flow; air should be stable_ on a table. Then we relight it after a little minute by a burning source at top of candle. We can change source of fire for relighting every time. Once fired matches, once lighter and so on.

Other experiments are focused on two other elements that distinction between them is a little harder. We try relighting a simple candle that is turned off recently by setting up a burning source at top of candle.

Then we can change discussion subject by trying to relight a recently turned off candle's thread singly. If paraffin wax had any effect on phenomenon, by bringing out its thread and testing it singly, experiments results must change basically.

Another aim. Distance. We construct a series of experiments. For relighting in standard equal laboratory conditions but at different distances. And we will retry this experiments for different diagonals of candles and finally different dimensions of burning fire of candle. The constituent paraffin is important but its experiment is not focused in this essay.

Some factors such as density of air and air flow of room are not discussed.

Let's continue, we then will reach some limits to relighting it from around it and we will gain a maximum limit for it. And some limits for angles from vertical line to relight it. These are our basic methods to reach limits of relighting.

4. Experiments and results

In this chapter we want to know that our tests how work and what results is gained through experiments. Our experiments must will be in a laboratory condition room. This could help us to approaching less effective changing test elements.

Experiments guide us to find out how relights of candle works. First constructed experiment. We did change of external sources and then move to reach a logical explanation for results. No difference among relighting times or intension of fire not observed. Important part is just heat, fire.

Now let's see about effect of paraffin wax and hot air. We describe experiment previously. By standard scientific conditions we be sure our tests are reliable. One of our theories was that hot burning air around source of fire will reach to candle, because top of candle vertically has hot air that is heated by candle before, then new burning source has a fire. Then if burning part of source that is made of burning air, fuel or material, and some heated around air; had more density than air of top of candle, it will flow down to candle and relight it while candle's upside air perhaps had some particles of burning object that will effect on air density.

Then we must study something. What is paraffin. It is some kind of alkane with general formulation of C(n)H (2n+2). Paraffin wax can its formula change among (n = 20) to (n = 40) in above mentioned formula. Let's show you some figures.

We will see in figure (1) that our products are H(2)O , CO(2) , OH , C(2) , some carbon particles that will stay unburnt. In figure (2) we see that some evaporated wax particles existed in black soot of candle. Unburnt carbon particles and evaporated paraffin wax particles.

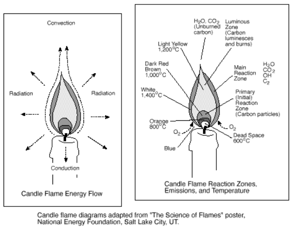

Fig. 1: Some carbon particles that will stay unburnt.

Fig.2: Some evaporated wax particles existed in black soot of candle

Note we can not say that because burning is stopped , we have no flow of unburnt carbon particles in the air. So answer is both of them.

For final experiments that we should change its diagonal and also its burning fire dimensions.

Results shows our flammable distance around candle has a limit. Actually it could not be relight by distance greater than 25 centimeters in average. It is 10.0 centimeters vertically above for our smaller candles. Limit for angle is 25 degree from vertical line. But has not observed any especial difference to intension of relighting among different angles.

Note our smallest candle mentioned bottom table.

Note we can change burning fire part of candle by changing its thread's length is out.

5. Example of Results

Candle's Diagonal	fire dimensions	maxi dist verti	angle limit
1.0 Cm	1.0 V 0.7 H	10 .0 Cm	25 Deg
1.5 Cm	1.5 V 1.1 H	14 .0 Cm	25 Deg
1.7 Cm	2.2 V 1.4 H	19.0 Cm	25 Deg
2.0 Cm	3.0 V 1.8 H	25.0 Cm	25Deg

We will face with a round figure around candle above it. It is rely on candle's diagonal length and how much candle's burning thread can produce fire, fire measure while burning is next factor that is related to its thread. And we can gain a maximum with a 2 centimeters diagonal with a burning fire with 3 centimeters vertically and 1.8 centimeters horizontally dimensions.

MATHEMATICS :

Max Dis = (Diagonal + Fire Length) * (Relation Constant)

Relation Constants :

5.00	4.66	4.87	5.00

AVG = 4.88 (non unit)

Finally :

Max Distance = (Diagonal + Fire Length) * (4.88) [General Linear Formula]

**fire width is neglected because it is related to its length, so we can consider one of them.

LIGHT RINGS

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ABSTRACT

When an obstacle is put in the path of liquid jet, while jet meets some specifications, standing waves are created upstream of the obstacle. If the contact point of jet and obstacle is illuminated by laser beams, those standing waves act like an optical fiber and keep the light inside the jet. Laser beams after multiple internal reflections inside the jet, create rings of light around the jet. In this paper, first we investigate the phenomena in terms of fluid mechanics, determining the wavelength of standing waves and, as the second part, we examine the rings in terms of optics.

Keywords : *Liquid jet, Optical fiber, Fluid mechanics, Rings*

1. Introduction

Collision of the jet with an obstacle, cause standing waves upstream of the obstacle. This phenomena can be observed in low velocity jets of household tap. About this phenomena there aren't much papers in relation to an analogue phenomena called capillary waves on fluid cylindrical. The analyses about capillary waves, deal with the instability that cause the cylindrical eventually become droplets. The first person who investigated this phenomena was Rayleigh which dated back to last century. He assumed waves of form $e^{-i(kz-\omega t)}$ on a jet with radius r and velocity u in the direction z with surface tension σ and density ρ and wave number k , he obtained this equation

$$\omega^2 = \frac{\sigma I_1(kr_0)}{\rho r_0^3 I_0(kr_0)}(kr_0)(k^2r_0^2-1)$$

In most of the papers which are published about standing waves in fluid cylindrical, the base of the analyses is the equation above. In these papers, the effect of viscosity is and also we face with lack of experimental data in this field.

In this article, we first investigate the phenomena without involving viscosity. We determine the effect of different parameters on these waves, which may haven't been investigated in any papers and then, we let the viscosity come in play and investigate standing waves, on highly viscous threads.

2. Theory

In order to analyze what physical effects are causing this phenomena, we should find out the behaviors of a liquid jet. First we examine the shape of a liquid jet.

2.1. The Shape of a Falling Fluid filaments (jet)

We investigate the shape of jets with high Re numbers, which the effects of viscosity on the shape and movement of the jet is negligible. Using Bernoulli's Equation for points A and B, we'll have :

$$\frac{1}{2}\rho v_0^2 + \rho g l + P_A = \frac{1}{2}\rho v^2 + P_B$$

According to Young-Laplace Equation that describes the capillary pressure difference sustained across the interface between two static fluids, due to surface tension, where R_1 and R_2 are the radius of local curvature of jet:

$$\Delta p = \sigma \nabla.\boldsymbol{n} = \sigma\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

That we'll get:

$$\nabla.\boldsymbol{n} = \left(\frac{1}{R_1}+\frac{1}{R_2}\right) \approx \frac{1}{r}$$

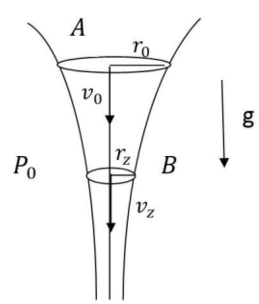

Fig. 1: The fluid cylindrical, accelerating under influence of gravity and surface tension.

Thus, with that simplification, the pressures of jet in points A and B are related to P_0 in this way:

$$P_A = P_0 + \frac{\sigma}{a}$$

$$P_B = P_0 + \frac{\sigma}{r}$$

Substituting into Bernoulli's equation and simplifications:

$$\frac{v_z}{v_0} = \sqrt{1+\frac{2gr_0z}{{v_0}^2}+\frac{2\sigma}{\rho {v_0}^2 r_0}\left(1-\frac{r_0}{r}\right)}$$

Now, we have the equation for the instantaneous velocity of the jet, we can easily obtain the equation for the radius of the jet using flux conservation:

$$Q = 2\pi\int_0^r v_z r_z dr = \pi r^2 v_z = \pi r_0^2 v_0$$

Hence we'll this equation:

$$\frac{r}{r_0} = \sqrt{\frac{v_0}{v_z}}$$

From this equation we can see that the jet will become narrow as it get more speed under influence of gravity.

2.2. Plateau–Rayleigh Instability

When a cylindrical jet flows in contact with air, there are some perturbations on the surface of the jet. These perturbations are always present and can be generated by numerous sources including vibrations of the fluid container or non-uniformity in the shear stress on the free surface. These disturbances form arbitrary. In fact, when a curve is made in the surface of the thread, because the surface tension acts in such a way to have the minimum interface with the gas phase (in order to reach the minimum potential energy) the surface will push back against any curvature to make the possible smoothest interface (mathematical proof that smooth shapes minimize surface area relies on use of the Euler–Lagrange equation). With the jet being pushed and then pulled back, we have a wave like shape.

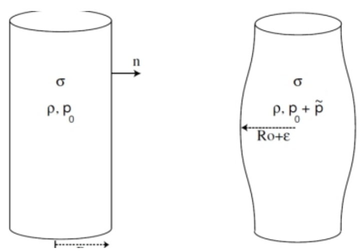

Fig.2: A cylindrical column of initial radius R_0 is shown in Steady State and Perturbed State

The radius of the stream R_1 is smaller , hence according to the young Laplace equation the pressure due to the surface tension is increased. Likewise at the peak the radius of the stream is greater and , by the same reasoning pressure due to the surface tension is reduced. If this was the only effect, we would expect that the higher pressure would squeeze liquid into the lower pressure region in the peak. In this way we see how the wave grows in amplitude over time.

But these two effects, don't cancel each other, as long as the effect of R_2 dominates the effect of R_2 the wave decays over time but in opposite situations, the wave grows over time. It is found that unstable components (that is, components that grow over time) are only those where the product of the wave number with the initial radius is less than unity.

$kR_0 < 1$

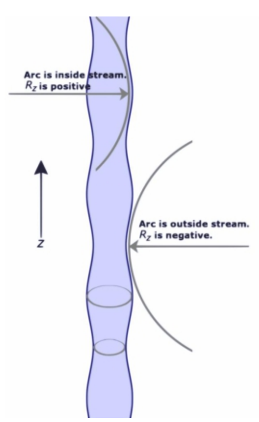

Fig. 3: Perturbations along a cylindrical jet

3. Main Explanation

Now, we investigate these waves in presence of an obstacle which is being pushed along the cylinder from one end. That growing wave will be compressed in length. By shifting the frame of reference, obstruction is moving upstream in the shifted frame of reference, that obstruction affects only the disturbed cylindrical surface. The jet itself continues to flow through it. It might be more helpful to say that we are witnessing the foreshortened history of the early, not-fully-developed, waves and again by changing the frame of reference and stand on the jet, those travel up above the obstacle with the same velocity as the jet which is falling in the exact opposite direction. Hence, those waves are stationary are observed like standing waves.

4. Materials and Methods

In our experimental study, we investigate effects of parameters on standing waves and confirm our main explanation due to our experimental results.

By changing the velocity we found that the wavelength of standing waves significantly is affected by velocity of the jet .

Increasing the velocity cause momentum increase. Hence our developing waves are more compressed in high velocity. More the Plateau Rayleigh are compressed, less the wavelength of standing waves will be. So, in high velocities we have standing waves with small wavelengths.

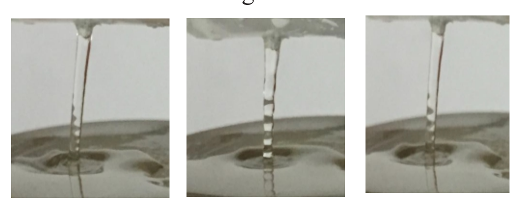

Fig. 4: Wavelength of standing waves is a function of jet velocity. Figure shows different velocities with the same radius

In case of investigating how does radius of the jet affect on standing waves, we canceled the effect of radius on velocity of the jet by experimenting different radiuses under the same velocity. Effect of radius on standing waves is even more than the effect of velocity. Because changing radius except affecting on the wavelength, will increase the velocity which itself affects on waves.

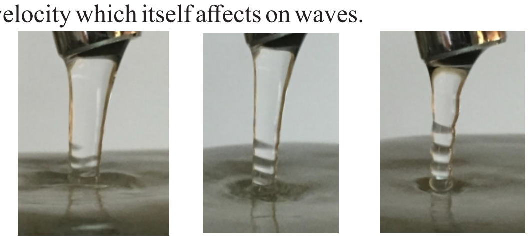

Fig. 5: Increasing the initial radius of the jet, causes wavelength of standing waves being decreased

A surprising result is that the wavelength of standing waves is independent of radius in high velocities. The most important parameter which affect on standing waves is surface tension of jet in contact with air. Again in changing the surface tension of the jet, we considered that surface tension will affect on jet velocity. In order to cancel this effect, we experimented different surface tensions under same velocities.

Surface tension is the main reason of this phenomena and is the most effective parameter. Due to our theory, increasing surface tension cause Plateau Rayleigh waves being increased. Hence, wavelength of standing waves are bigger in higher surface tensions of jet. Another surprising result is that in high velocities, wavelength of standing waves is independent of jet surface tension.

5. Conclusion

Using our experimental results, we found out how wavelength of standing waves changes under different velocities and radiuses of the jet. We also investigated the main parameter, surface tension. We figured out a significant change in wavelength of standing waves by changing the surface tension, which proves our theory that is based on capillary actions. These waves, act as an optical fiber which keeps light inside.

FUTURE WORK

As our future works, first we have plan on investigating this phenomena in presence of viscosity using Navier Stokes equations.

Also, we have plan on experimental study of viscous threads, Using Capillary number to state a limit between capillary actions and viscosity effects which eventually will tell us in what capillary numbers, this phenomena occurs .

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TRAJECTORY OF A ROLLING OBJECT ON A ROTATING DISC

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ABSTRACT

In this paper, we survey on the motion of a rolling object on a turntable exhibiting trajectories without being expelled from the disc like revolving in a stable circular orbit or coming toward the center of the disc that depends on initial conditions and range for observation of a specific trajectory is limited. Based on references frequency of the turntable and rolling friction force are the most important parameters affecting on this phenomenon. According to our experiments both of frequency of the turntable and rolling friction force can effect on velocity and mass center velocity of the rolling object that in some of situations make the rolling object come toward the center.

Keywords : *rolling object, rolling friction, frequency of turntable*

1. Introduction

When a rolling object (sphere, disc, ring,…) is put on a horizontal rotating disc although we predict that the rolling object will be cast away from the turntable (because of the Centrifugal force), interesting trajectories will be observed while the rolling object is bearing on turntable without being expelled from it like charged particles absorbing in an electric field .Frequency of the turntable and rolling friction force are the most important parameters affecting on the trajectory of the rolling object. We need to know about rolling motion for our investigation. If an object rolls without slipping, then the bottom of the rolling object must be momentarily at rest. Rolling without slipping can be thought of as the motion of the center of mass plus rotational motion about its center of mass.

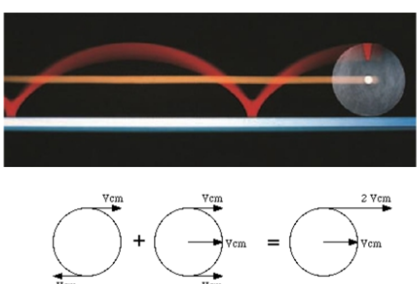


Fig. 1: Rolling motion of a rolling object

As shown in figure (1) when a rolling object has rolling motion it rotates about the point of contact with the ground.

Rolling friction is the resistive force that slows down the motion of a rolling ball or wheel. This type of friction is typically a combination of several friction forces at the point of contact between the wheel and the ground or other surface (Fig

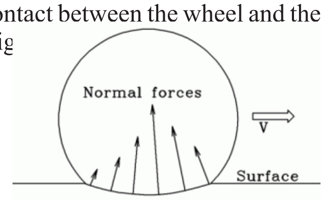


Fig. 2: Several friction forces

Amount of rolling friction is calculated by following equation:

$$F_r = u_r W$$

Where, F_r is the resistive force of rolling frictional force ,u_r is a constant, called the coefficient of rolling friction for the given surfaces of contact-which is dependent on elasticity and deformation amount of the surface- and W is the entire weight of the rolling object including the rolling mechanism.

In this problem rolling friction force plays a major role so discussion about effect of rolling friction is essential to investigate trajectories of spheres and rings on a rotating disc.

We investigated behaviors of spheres and rings (or discs) on the rotating disc separately.

2. Methodology

During our investigation we found articles which dealt with this problem using force, torque and angular motion equations and imaginary methods to make the problem understanding simpler. But our main way to solve the problem was experimental method. We produced a horizontal rotating disc and observed different types of trajectories for spheres and ring recording the rolling object motion by digital high speed camera. We get our experimental data using "Tracker" software (Fig. 3).

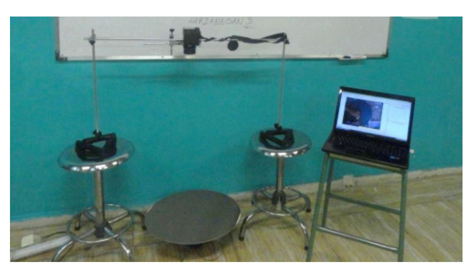


Fig. 3: Experimental setup

3. First Attempt: Different Observed Types of Motion for Spheres

We can easily observe these types of trajectories doing simple experiments through a turntable and a sphere.

1. The ball's center of mass goes in a curved path and expels from disc (Fig. 4a).

2. The ball's center of mass runs on the disc and additionally exhibits loops. (Fig. 4b)

3. The ball's center of mass turns in a stable circular orbit that depends on the frequency of the rotating disc.(Fig. 4c)

4. The ball's center of mass is at rest and has no motion.

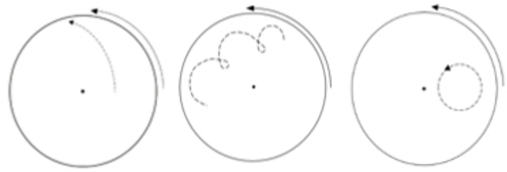


Fig. 4: (a) (b) (c)

The ball expells from disc. The ball makes loops The ball runs on a circular orbit

Fig. 5: The ball is being expelled from the disc

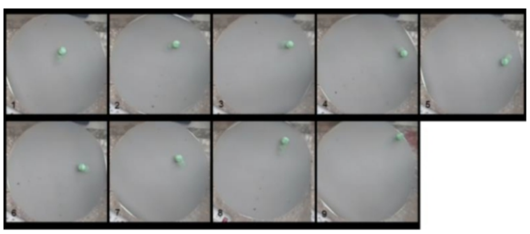


Fig. 6: The ball makes loops

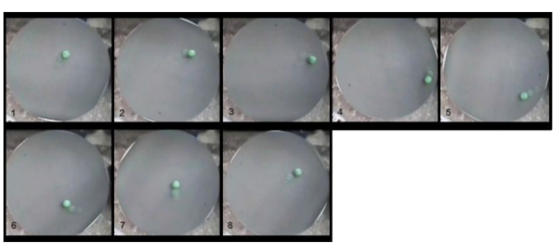


Fig.7: The ball turns in a circular orbit

4. Analyze of Trajectory of Spheres

Here r, R, ω and Ω are the sphere radius, the radial distance of the sphere from disc center, angular velocity of the sphere and angular velocity of the turntable respectively.

1. In this situation the linear velocity of the turntable is much more than the surface velocity of the sphere:

$$\omega \times r = v + \Omega \times R$$

2. friction force makes the ball roll on rotating disc and the ball has angular velocity perpendicular to the velocity of the disc and it keeps its rolling direction while the direction of the velocity of the rotating disc keeps changing but the disc can't change the rolling direction of ball (because of the angular inertia of the ball) so ball's contact point runs on the disc-we have sliding motion additionally-as a result the ball get closer to the disc but the surface velocity of the ball is less than the linear velocity of the turntable($\omega \times r = v + \Omega \times R$) so the ball gets to be expelled from the disc but friction makes ball's surface velocity increase and the ball repeat the trajectory back to back.

3. The ball keeps its velocity (because of its angular inertia) while it's coming toward the center so when it gets closer to the center its surface velocity is more than the linear velocity of the turntable at the point of contact. As a result it moves in opposite direction with its last movement and makes a circular orbit.

According to our experiments: $\omega_0 = (2.7)\ \omega_d$

Where ω_0 is the frequency of the circular orbit and ω_d is the frequency of the rotating disc.

4. To keep sphere's center of mass at rest (have no velocity relative to outward coordinate system) its surface velocity must be equal to turntable velocity:

$$r\omega = R \times \Omega$$

V. Second attempt: motion of rings

There is no complete written theory for the trajectory of rings and discs in references so we started an investigation to analyze motion of them.

Rings and balls have various propinquities but rings because of the fulcrum have restriction against rolling with some of directions so the rotation of the turntable effects on the ring differently and makes it rotate around its diameter and with direction perpendicular to the turntable surface.

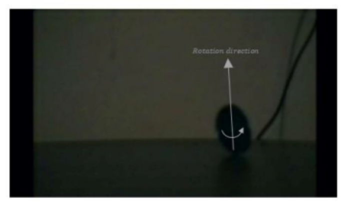


Fig. 8: There is rotation around the diameter of rings and changing mass center velocity direction during motion of rings

Discs and rings show .approximately the same interesting trajectories but inertia and angular inertia are actually important which is different for rings and discs. In figures (9) and (10) you can see the trajectory of a ring on the turntable.

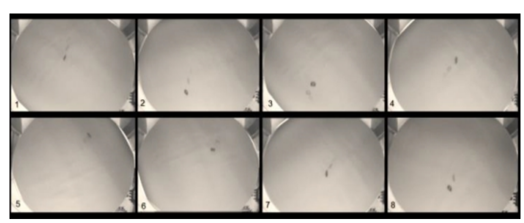


Fig. 9:Trajectory of a ring on rotating disc

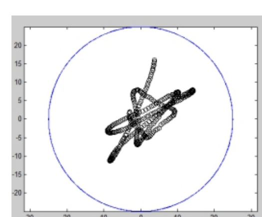


Fig.10: Trajectory of a ring on the turntable

5. Result

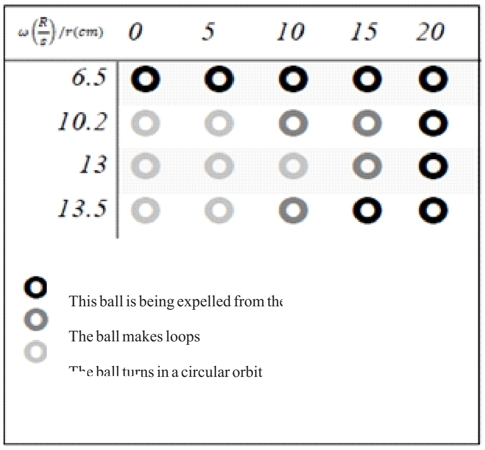
In figure (8) you can see the different trajectories of the ball on the turntable. We changed initial conditions and achieved table (1).

As shown by figure (8) the trajectory of the ball is dependent on initial conditions and the range of observation for a trajectory is limited to specific initial situation.

6. Conclusion

A sphere or a ring (or other type of rolling object) can bear on a rotating disc without being expelled from the disc exhibiting different types of trajectories that depends on initial conditions like frequency of the turntable and radial position of the rolling object and ratio of initial velocity of the rolling object into the velocity of the rotating disc and the range of observation for a trajectory is limited to specific initial situation. Type of friction affecting on the rolling object is different for different situations. (For example rolling friction for rolling motion and both of rolling friction and sliding friction for motion of a rolling object with sliding motion additionally).

Table 1: observed trajectories during experiments in different initial conditions



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ACOUSTIC LENS

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A B S T R A C T

Fresnel plate consists of radially symmetric zones. Zones alternate between opaque and transparent, and are spaced so that wave transmitted by the transparent zones constructively interferes at the desired focus. Modeling and experimental results of a flat lens for use in air are presented and the optimized design parameters are used to fabricate the lens. The theoretical calculation for the focal length is determined to be 20.0 cm and the incident wave length of 3500 Hz. The results show a sharp focal spot with very high amplitude.

A R T I C L E I N F O

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Keywords : *Acoustic Lens, Sound Waves, Focal Point, Diffraction, Interference*

1. Introduction

Acoustic Fresnel lenses have a great application in acoustic microscopy and different category. They have emerged as an alternative to the conventional due to ease of fabrication even with the low efficiency of 40% of input waves[2]. Different from usual lenses, Fresnel lenses use diffraction mechanism to redirect waves at the desire focus.

Fresnel lenses with concentric rings are widely used in optical applications, however a similar principle can be used to focus acoustic waves. Designing and producing an acoustic lens and investigating its properties, such as amplification, and its dependence to relevant parameters is the main goal of this paper Many methods have been studied to focus sound waves such as using Fresnel binary lens consist of alternating transmitting and opaque rings as a scattering elements . Due to diffraction and interference theory zone plates can be able to focus the sound waves because of their wave behavior. Other way that has been used to focus sound waves was using a regular array of cylinders . These cylinders also work by diffraction and interference theory too. In these two methods that we talked about the goal was to make constructive interference of waves and also try to make it in one point rather than many of them, then more sound pressure can be detected. These two methods are good for high frequencies of sound, because in low frequencies a big structure is needed; And the solutions was just for plane sound waves.

Some different mechanisms to achieve sound collimating have also been explored. Like using negative refraction in metamaterials that is because of different refractive indexes then it may be possible to focus acoustic waves.

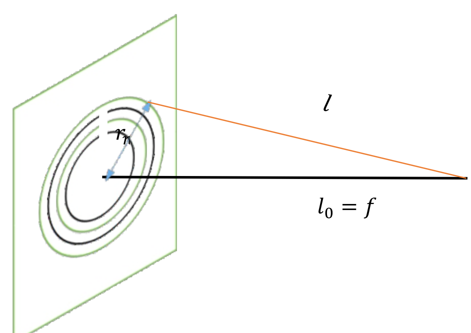
In this paper we investigated the effect of relevant parameters on an acoustic lens amplification and introduce some methods to design it with the best quality. Also make it appropriate for low frequencies of sound and see the effect of spherical source.

2. Methodology

Our method for an appropriate design of the lens was using COMSOL software for simulations and numerical solution to reach a good design that can make constructive interference on lens's axis. Except previous researches our numerical solution has been done for spherical wave front which is more close to reality. Effect of each parameter and boundary condition has been considered in our simulations. Another reason to use simulation is that number of possible designs that can focus sound waves is not limited, but we wanted to find optimum of them. After that making experiment's setup to check our results from simulations and compare with experimental data because finding the effect of each parameters and then finding the appropriate one by experiments was hard and waste our time.

3. Theory

a) Basic calculations :



By writing a simple Pythagorean relation, diameters can be calculated.

$$f^2 + r_n^2 = l^2$$

As we now. $l - l_0 = \frac{n\lambda}{2}$

so

$$\boldsymbol{f^2 + r_n^2 = (f + \frac{n\lambda}{2})^2}$$

$$r_n^2 = n\lambda f + \frac{n^2\lambda^2}{4}$$

The term $n^2\lambda^2/_4$ represent spherical aberration .

b) Fresnel geometry

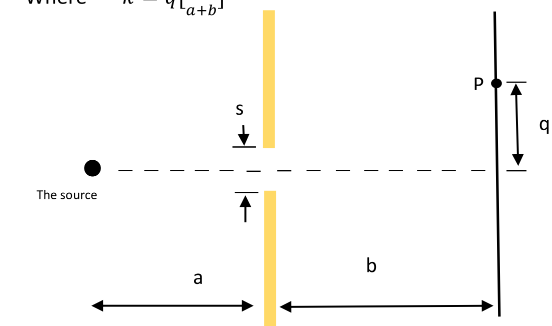
To calculate the intensity at point P, the geometry is setup in terms of the parameter v which is used with the Cornu's spiral.

$$v = v_1 - v_2$$

$$v_2 = [\frac{s}{2} + k]\sqrt{\frac{2(a+b)}{ab\lambda}}$$

$$v_2 = [\frac{-s}{2} + k]\sqrt{\frac{2(a+b)}{ab\lambda}}$$

Where $k = q[\frac{a}{a+b}]$



These equations would be useful in the days before computer programs like "cool edit" -that has been used in the experiment- but today one can compute the intensity of different points.

When a set of incident waves strike the lens, the obstacle is not a simple geometric shadow, it is a diffraction pattern. When the source wave is not distant and the incident waves are not plane, the Fresnel diffraction pattern can be observed and its theory is, unsurprisingly, a little more difficult than the theory for Fraunhofer diffraction.

4. Experiment

Here we explain 2 different symmetry designs.

4.1. First model

To clarify one of the techniques consider an array of nonoptimized circles in x-y plane with the axial symmetry x (Fig. 1a). These circles by transition from 2D to 3D by extruding them along z axis can make a 3D acoustic lens consist of cylinders as a scattering elements capable of focusing sound in a line parallel to the extrusion direction. The acoustic waves impinges the structure from the left. We considered PML (perfectly matched layer) for boundary conditions to transmit the sound perfectly. The results of simulation show us sound pressure in all point toward the structure. Some pair of the cylinders have been discarded to optimize the design because they make a destructive interference in our focal point (Fig.1b). So we discarded some of them. By Changing the position and radius of cylinders and see the results we tried to find the appropriate design.

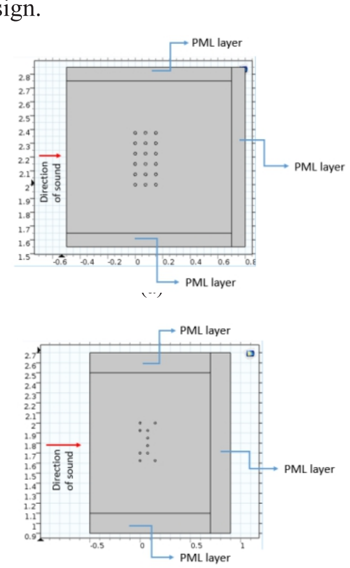


Fig 1: a) Structure of simulation with nine pair of cylinders. b) some pairs of cylinders have been discarded

Absorption, transition and reflection of cylinders can also effect on sound pressure in focal points. These three properties are related to the material used for make cylinders. To consider effect of these three we must choose something which is more close to reality. The material with sound velocity of 1040 m/s and density of 4.1 kg/m^3 are chosen as the material of cylinders. About the effect of sound frequency, if one setup be good for one frequency it also can focus sound for other frequencies but with a small change in lens dimensions. Thus simulations done with same frequency and after finding one appropriate design, the design examined by various frequencies then the best frequency for maximum sound amplitude found.

4.2. Second model (Fresnel zone plate)

Simulation

Fresnel binary lens consist of concentric rings is the second method to focus sound wave, that we explain this method here. Using Fresnel lens formula ($r_n = \sqrt{nf\lambda}$) that gives the radius of nth rings for determined focal length. λ is the wavelength of sound. Then the 2D simulation done using axisymmetrical method. The boundary conditions were PML too . Sound emits the structure from bottom. Then the results of our simulations gave us the appropriate setup to focus sound waves. The material used for rings was same as the material of cylinders. And also the same frequency. Here like before if one design can be good for one frequency it also can be useful for other frequencies but with some changes in dimensions. Here the relation to change dimensions is $r_n = \sqrt{nf\lambda}$ (Fig. 2).

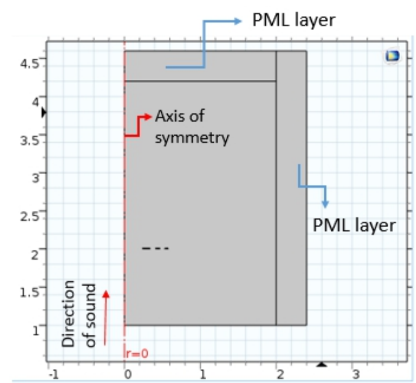


Fig 2: Second model

5. Numerical Solution

Calculations have been done for Fresnel zone plate to find out sound amplitude in each arbitrary point (x1,y1). The sound source is assumed spherical so the path length difference has been calculated before emitting the structure and after it to the point(x1,y1)(Fig. 3).This figure shows a 2 dimensional Fresnel zone. Blue lines on x axis shows rings. The width of the rings decreases by increasing distance from the central point $O(x_0,y_0)$. The space between $-r_1$ and r_1 didn't assumed opaque to transmit the sound. To find out the amplitude of the wave traveling along m1-l1 path (or others) and reaches to the point p, we need to know the remainder of division of l1+m1/ λ (here we called that mod(ln+mn,landa). The amplitude is given by the equation:

$$A = \sin(\mathrm{mod}(ln+mn, \lambda)/2\pi$$

This amplitude A, is the amplitude without considering the effect of distance from the source point to the point p that can make the intensity less. To solve this problem we considered I as the initial intensity of sound. So the real intensity at the point p can be found by:

$$A = [\sin(\mathrm{mod}(ln+mn, \lambda)/2\pi]/4\pi r^2$$

we divided the intensity to $4\pi r^2$ that is the surface of a sphere sound traveled to consider the effect of traveled distance on total amplitude.

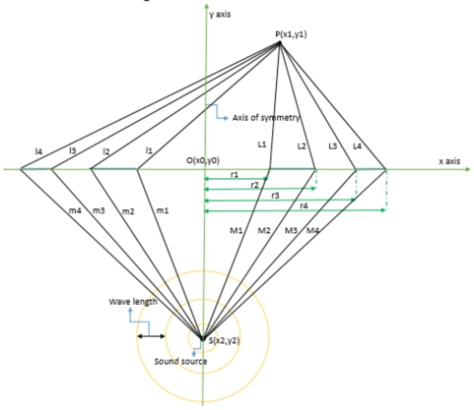


Fig. 3 : 2D scheme of Fresnel zone plate by a spherical sound source P is any arbitrary point and the black lines from source to the point p show the path difference. The rn introduce the radius of nth ring

6. Results of These Two Models

1.First model results

The final design that we reached was the design shown in (Fig. 4). An array of cylinders with outside radius 1.59 cm and inside radius of 1.41 cm and the material in which the sound speed is 1040 m/s and the density is 4.1 kg/m^3.

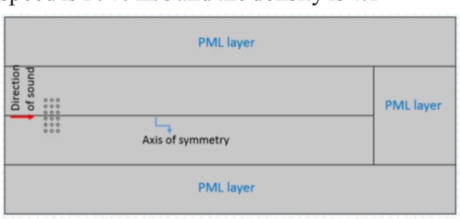
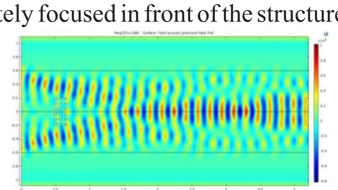
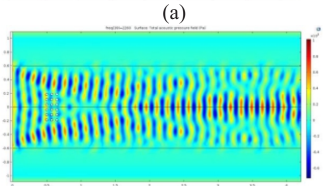


Fig. 4: The final design that was appropriate for our goal

This structure examined for various frequencies from 1500 Hz to 3000 Hz by the step of 20 Hz. The results was appropriate for the frequencies 1980 Hz, 2000 Hz, 2260 Hz and 2900 Hz (Fig.5). This figure shows the acoustic pressure in all points. The sound wave has been approximately focused in front of the structure.



(a)



(b)

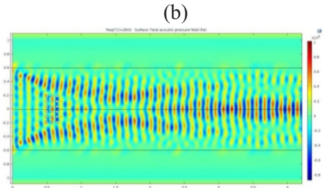


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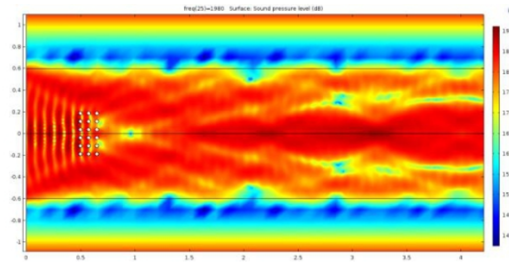
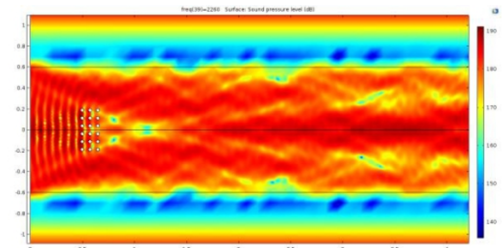
Fig. 5: Results of acoustic pressure for frequency a) 1980 Hz b) f=2260 Hz c) f=2900 Hz. The red parts have the most acoustic pressure

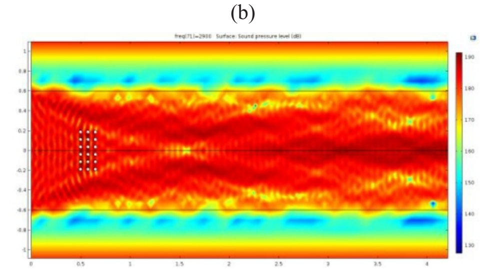
The results for these 3 frequencies for the sound pressure which human can hear is shown in (Fig.6).



(a)



(b)



(c)

Fig. 6: The results of sound pressure in all points towards the structure for the frequencies a)1980 Hz b)2260 Hz c)2900 Hz

The maximum and minimum sound pressure place changes by sweeping on frequencies (Fig. 7).

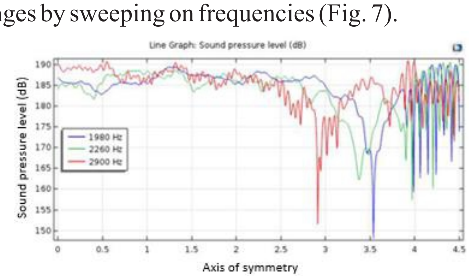


Fig.7: Comparing sound pressure for 3 frequencies. Red one is frequency of 2900 Hz, green one frequency 2260 Hz and the blue one for the frequency of 1980 Hz.

2. Second model results

The 2D design of Fresnel zone plate is shown below (Fig.8). The diameter of rings considered 0.002 m. And the material used for rings was the same as the material used for cylinders before. (Sound speed=1040 m/s and density of $4.1 kg/m^3$).

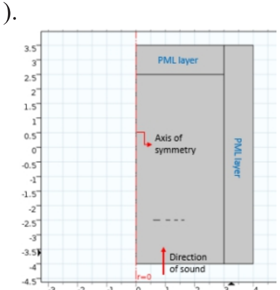


Fig. 8: 2D appropriate design of Fresnel zone

This design examined for various frequencies. From 2500 Hz to 3000 Hz by the step of 50 Hz and the maximum sound pressure measured in each simulation. The peak sound pressure for 2650 Hz had the best result (Fig. 9).

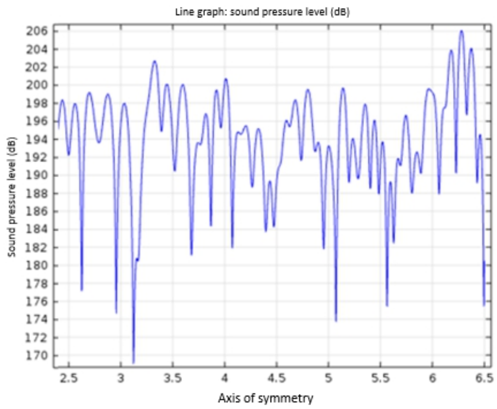


Fig. 9: Sound pressure on each point on the axis of symmetry of the design. The maximum sound pressure is 206.115 dB at the distance 3.75 m in front of the structure

7. A Handmade Lens

The lens consists of Styrofoam with radially symmetric zones. A signal generator with specific frequency and amplifier connected to speaker. In order to find the experimental focal point, placing the microphone in the different location is needed. By analyzing and comparing the intensity of the different focal points, the sharpest focal point with very high amplitude can be observed (Fig. 10).

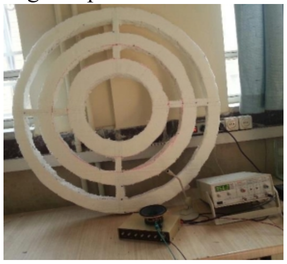


Fig. 10: Handmade lens

The microphone had been recorded the sound and with "cool edit pro" the intensity can be calculated (table 1).

Table 1: Intensity by the lens

X(cm)	Y(cm)	Intensity(dB)
3.5	21.5	-25.49
3.5	35.0	-25.66
-6.5	32.5	-27.95
*0.5	39.0	-20.96
-3.5	35.0	-26.44
6.0	30.0	-30.12

x=the horizontally distance of microphone from the center of the lens; y=the vertically distance of microphone from the center of the lens. *the sharpest intensity among the measurements.

Table 2: Figure (2.5) Different amplitudes for the sharpest focal point (0.5, 39.0) lead to different intensities

Intensity(dB)	Amplitude
-25.30	3
-23.94	4
-20.96	5
-18.63	6

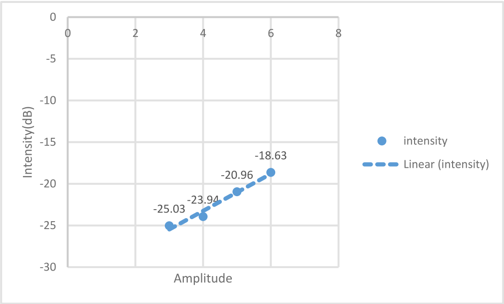


Fig. 11: By increasing the amplitude the intensity of the main focal points increased

Table 2: Intensity A is when the lens is set to the setup and Intensity B is the Intensity without lens and the intensity Gain is portion of intensity A to intensity B.as it can be observed the lens is amplifying the amplitude

amplitude	Intensity A(dB)	Intensity B (dB)	Intensity Gain
1	-34.88	-31.21	1.117591
2	-31.78	-28.44	1.11744
3	-25.03	-22.33	1.120914
4	-23.94	-21.3	1.123944
5	-20.96	-18.55	1.129919
6	-18.63	-16.38	1.137363

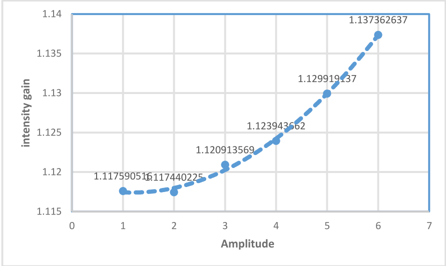


Fig. 12: By increasing the amplitude the intensity gain is increasing slightly

7. Conclusion

In this paper we talked about the methods already used to focus sound wave and their weaknesses and we tried to introduce the design that can focus sound. COMSOL software used to discover a lens capable focusing sound. The effect of relevant parameters that can effect on amplification of the lens investigated and also boundary conditions considered. So some designs introduced. An array of cylinders is able to focus waves in appropriate conditions.

Discarding some pairs of cylinders avoided destructive interference at the focal point , so we reached to that condition. The final system examined by many frequencies and the frequencies that could focus sound rather that other founded. Fresnel zone plate can also be helpful to focus sound. For a determined focal length we calculated the radius of rings then simulate them. Sweeping on frequencies gave us the frequency that has a maximum peak. These two designs can made and use to focus sound waves.

Also We have done the experiment with a handmade Styrofoam lens which has a low efficiency because of errors of fabricating, thus the theoretical calculation for the main focal point was different from the experimental focal point. The experiment shows that by increasing the amplitude the intensity of the focal points would be increased also the intensity gain is calculate and the result shown the amplification of the lens. The Fresnel lenses use the diffractive properties to focus wave which can be explained with Fraunhofer diffraction theory.

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STATIC SPEAKER

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ABSTRACT

Sound is a vibration that propagates as wave of pressure and needs a medium to be transmitted. At first, let's have a look at speakers and see how they work. What we are going to do, is using heat to produce and amplify sound. This approach leads to a phenomenon called "thermoacoustics effect". This effect can be observed in glass blowers, where blowing a hot bulb at the end of a cold narrow bulb produces sound. To investigate the parameters in this phenomenon, our data have been collected and analyzed from several experiments.

Keywords : *Sound Waves, Vibration, Thermoacoustic Effect, amplify Sound*

1. Introduction

Sound is a vibration that propagates as wave of pressure and needs a medium to be transmitted. At first, let's have a look at speakers and see how they work.

As shown in figure (1), it consists of a circular magnet which is the North Pole. Within the cone, there is another magnet which is the South Pole, surrounded by the voice coil. Suspension (spider) supports whatever that is underneath it and allows the cone to move freely up and down.

How does it exactly work?

As we know, there is a magnetic field between the magnets, so if we put in current in the coil, based on the right-hand rule, we will have a force in a direction (upwards or downwards). Now if we change the direction of our current the force will be in the opposite direction of what it used to be. If we continue changing the direction of the current, the voice coil will keep moving up and down as well as the cone. For having this movement, we have to connect the coil to the AC supply so that it can have a particular frequency.

But how can we hear the sound?

As mentioned before, the cone is attached to the coil, so they have an equal vibration. This movement of the cone, pushes the air and makes what it's called "compression waves", and this is actually the sound waves that we can hear.

What we are going to do, is using heat to produce and amplify sound. This approach leads to a phenomenon called "thermoacoustics effect". This effect can be observed in glass blowers, where blowing a hot bulb at the end of a cold narrow bulb produces sound.

2. Theory

Sound is a wave of pressure, which means periodic change in pressure is needed to produce sound. Since common speakers are used in air and the medium is gas in this case, we focus on propagation of sound wave in air without loss of generality. From thermodynamics we know that pressure of a gas is proportional to its temperature for an ideal gas, and depends on temperature in more general case for real gases according to Van Der Waals equation. This is the point, we instead of changing pressure frequently to produce sound, we can change temperature of air near our device and change in temperature will result in change in pressure, so we can produce sound by changing temperature frequently. Increasing temperature of air requires thermal energy to increase internal energy of medium. According to thermodynamics' first law:

$$\delta U = \delta Q - \delta W \tag{1}$$

$$\delta U = V\delta p + p\delta V \tag{2}$$

Where "U" is internal energy of system, "Q" represents heat transferred to the system and "W" is worked done on system.

Thermoacoustics speaker has no moving parts, so if we assume control volume is volume in semi-sphere of radius "r" on top of our speaker, there shouldn't be any mechanical work on boundary, so there will be no works an also no change in volume.

$$\delta U = \delta Q \tag{3}$$

$$\delta U = V\delta p \ (Eq.4) \tag{4}$$

We found out that we need a heat source which can frequently heat up the system and cool it down. We are going to use electrical power and Joule heating effect as heat source. When the current I is passed through a resistor, it makes the resistor hot and the heat coming off the resistor flows out into the air. The energy used by the resistor is converted entirely to heat. As we told before, we don't need to just increase temperature and also need to cool it down and do it frequently. If we use DC current, it just heats up the device and then air, so we can't produce sound in this way. But what if we apply AC current? An alternative current passes through the resistor and power produced is:

$$P = \frac{1}{2}(RI^2 + RI^2\cos(2\omega t)) = P_{DC} + P_{AC} \tag{5}$$

Where, "ω" is frequency of AC current, "P" is power, "I" is maximum current, and "R" is resistance. As you can see, Power consists of two terms, the first term is called "DC power" and the second one is called "AC Power". DC power just heats up the device and as we mentioned before, this power can't produce sound, but AC power can do it. AC power changes with time and doesn't have constant heat production, which means it depends on time. So during a cycle. Air can be cooled through convection so temperature of air decreases when our device AC power is at its minimum value and increases, when AC power is maximum and near it. So what produces sound is AC power and DC power just increases temperature of our device. We need a resistor which has a high thermal effusivity (a measure which says how fast a material can transfer heat) and also be a perfect electric conductor. This resistor should be as thin as possible, if it's not, heat will be transferred by thermal conductivity between layers of resistors and it reduces speed of heat transfer. Heat is also transferred between layers of resistors through its thickness while our goal is to transfer heat to air, in other words resistor is used as a heat sink which needs. Resistor should transfer heat to air and it occurs through convection so it must have a surface to be able to transfer heat through convection better. We offer to use graphene as resistor. But why graphene? Graphene is an allotrope of carbon and consists of layers, in each layer carbon atoms are bonded to each other with covalent bonds and layers are connected to each other due to van der Waals force. So we expect thermal conductivity not to be isotropic and changes with direction. In fact thermal conductivity K reaches about 3000 W m^1 K^{-1} in the parallel to planes direction, and 5 W m^{-1} K^{-1} orthogonally. So when number of layers decreases, we can assume that heat transfer in graphene occurs only in parallel to plane and we can neglect it. So if we use thin graphene layer, we can assume that as electric current passes through graphene, it heats up graphene and all heat is in a thin layer of graphene and this heat is transferred to air through convection and heat transferred from the surface which is in contact with air is to other layers is negligible, so efficiency increases. Graphene also has a high thermal effusivity which means it can transfer heat faster in comparison with lots of materials.

Heat transferred to the system is summation of heat transferred to graphene and air:

$$\delta Q = \delta Q_a + \delta Q_g \tag{6}$$

also we know that:

$$\delta Q_a = \frac{C_a}{C_a + C_g}\delta Q \tag{7}$$

$$\delta Q_g = \frac{C_g}{C_a + C_g}\delta Q \tag{8}$$

$$C_g = m_g c_{p,g} = \rho_g S d_g c_{p,g} \tag{9}$$

$$C_a = m_a c_{p,a} = \rho_a S d_a c_{p,a} \tag{10}$$

Where C is thermal conductivity in constant pressure, S is surface, d is thickness, c is specific heat capacity and ρ is density and index "a" is for air and g is for graphene. Since surface of air which is in contact with graphene is equals to graphene surface, so we didn't use index for S." d_a" is skin depth of the thermal boundary layer of air and defined as a distance where if temperature of heat source changes, after $\frac{1}{f}$ seconds , air is affected by change in temperature and f is frequency .

$$d_a = \sqrt{\frac{k_a}{\rho_a c_{p,a}}} \tag{11}$$

If we use this in Eq.7 we will have:

$$C_a = e_a . S . \omega^{-\frac{1}{2}} \tag{12}$$

Where "e" is thermal effusivity. We can define effusivity for graphene as:

$$e_g = \rho_g d_g c_{p,g} \sqrt{\omega} \tag{13}$$

Which has same dimension with e_a.
So we have:

$$\delta Q_a = \frac{e_a}{e_a + e_g}\delta Q = \frac{e_a}{e_a + e_g} . \frac{P_{AC}}{f} \tag{14}$$

Using Eq.3, Eq.4 and Eq.14 at the same time will give us:

$$\delta p = \frac{e_a}{e_a + e_g} . \frac{P_{AC}}{f} . \frac{1}{V} \tag{15}$$

"V" is volume of control volume which we defined before as a hemisphere, so:

$$V = \frac{2}{3}\pi r^3 \tag{16}$$

Since wave is sonic, it travels at speed of sound. We want to assume our speaker to be a point source. This requires dimensions of graphene be much smaller than wavelength. So if we want to produce a sound of frequency 100 Hz, speed of sound in room temperature and 1 atmosphere pressure is approximately 300 m/s, so wavelength will be 3 meters and that will be surely much greater than dimensions of graphene we will use. So this can be a reasonable assumption to think of our speaker as a point source. If we assume speed of sound as "Va", then after 1/f seconds, wave will reach the distance "r":

$$r = \frac{Va}{f} \tag{17}$$

$$V = \frac{2}{3}\pi(\frac{Va}{f})^3 \tag{18}$$

$$\delta p = \frac{e_a}{e_a + e_g} . \frac{3P_{AC} f^2}{2\pi V a^3} \tag{19}$$

Eq.19 gives us a relation between change in pressure and input power. But it needs correction. As sound wave travels through a medium, its energy attenuates due to viscosity and amplitudes of wave decreases exponentially with distance from point source due to formula:

$$A = A_0 e^{-\alpha z} \tag{20}$$

A" is reduced amplitude, A_0 is unattenuated amplitude of the propagating wave at some location, "z" is the distance which sound traveled and α is attenuation coefficient which probably depends on Prandtl number and viscosity of medium. The Eq.19 says that pressure is proportional to AC power and since AC power is a cosine wave, there will be an extreme point for AC power (and also pressure) when:

$$t = T = \frac{1}{2f} \ (here\ frequency\ of\ AC\ power\ is\ 2f)$$

After this time, wave reaches r_0 and has a maximum pressure and:

$$r_0 = \frac{Va}{2f} \tag{21}$$

So A_0 must have its maximum value (A_0= 1) at this distance and must decrease as wave propagates in air. So we can assume that: $A_0 = r_0 . F(r)$ and $r_0 F(r_0) = 1$. So we can correct Eq.20:

$$\delta p = \frac{e_a}{e_a + e_g} \cdot \frac{3P_{AC}f^2}{2\pi V a^3} A_0 e^{-\alpha z} = \frac{e_a}{e_a + e_g} \cdot \frac{3P_{AC}f}{4\pi V a^2} r_0 F(r) e^{-\alpha z} \quad (22)$$

We used AC current of frequency ω and AC power is 2ω . Since pressure is proportional to AC power, sound wave will have frequency 2 times of input frequency. Since oscillator can produce AC current of frequency 0 to even more than 20 KHz, this device can produce sound of any frequency. This Thermoacoustic device doesn't have any moving parts and can produce sound of all frequency and is limited just by frequency of oscillator. In Eq.19 we didn't consider dissipation of energy. Here we have heat transfer and air moves as its temperature and density changes, so energy dissipation may depends on Prandtl number. Since sound propagates through a fluid, it may also depends on viscosity of fluid. But Eq.22 includes energy attenuation and as we mentioned before, α probably depends on Prandtl and viscosity of medium.

Future Work:

1- Using analogy between Stokes' second problem to derive energy dissipation and skin depth thermal boundary layer.

2- Simulating device in Comsol to discuss about heat transfer in graphene and air.

3- Doing experiments on experimented results.

4- Amplifying sound

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COOLING JUG

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ABSTRACT

In the old days, a clay pot cooler (also called a zeer or pot-in-pot cooler) was often used for keeping foodstuffs fresh in very hot and dry areas. Water was used to cool the inner pot as it flowed through a porous surface (such as sand) and subsequently evaporated. What is the minimum temperature that can be achieved using such a device and what does this minimum temperature depend upon? Explain what determines the rate of cooling?

Keywords : *Zeer Pot, Refrigerator, Moisture, Thermal mass*

1. Introduction

In zeer pot, water evaporates through sand which has filled the gap between the inner pot and the outer pot, out of the outer pot. The water serves as refrigerant .The sand is considered as a thermal mass and helps moisture up the wall of outer pot's surface.

The zee rot will work better under direct sunlight because it will transfer a significant amount of energy to the system.

2. Theory

2.1 Relative Humidity

The water that is moving among sands, will evaporate much better in environment with low humidity in comparison to the high one. Because relative humidity is a measure that shows how much water can be held in the air. So if we put cooling jug in a low humidity place, the water will evaporate faster so the jug will be cooler faster and the temperature reduce more than when we put it in a high one (Fig. 1).

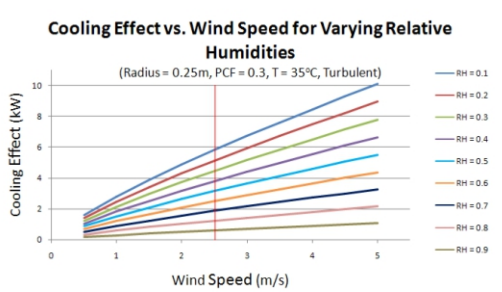

Fig. 1:(Cooling Effect vs. Wind Speed for varying Relative Humidity Levels (Device Radius = 0.25m, Permeability Correction Factor = 0.3, Ambient Temperature = 35 degrees Celsius, Turbulent Flow)

2.2. Permeability

Evaporate occurs through the outer pot, so the type of clay that pot has made out of is very important because of the "permeability". It is better that clay be permeable and porous so water can evaporate through it more easily, because water must keep going through the sand to replace the moisture that has evaporated and passed out through the outer clay. So the important measures here are diffusion rate and the permeability of the clay. The best type of clay that we can use is Earthenware (Fig. 2) .

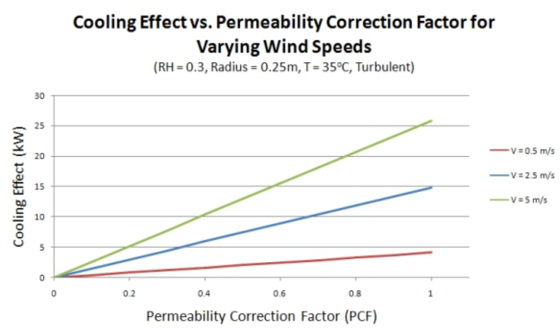

Fig. 2: (Cooling Effect vs. Permeability Correction Factor for varying Wind Speeds (Device Radius = 0.25m, Ambient Temperature = 35 degrees Celsius, Relative Humidity = 0.3

2.3. Area available for Evaporation

The pot surface area that evaporation occurs through it approximately calculated as:

Total Area = Surface Area of Spherical Portion of Outer Pot

+ Surface Area of Cylindrical Portion of Outer Pot

+ Surface Area of Exposed Sand in between Pots

The radius of the outer pot has been selected to vary the area available for evaporation (Fig. 3).

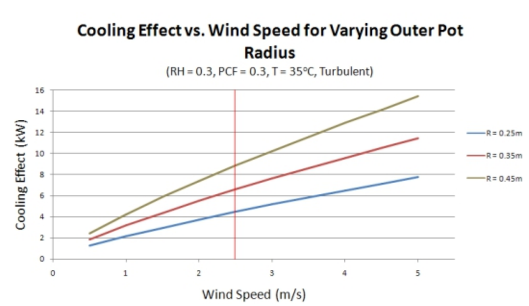

Fig. 3: (Cooling Effect vs. Wind Speed for varying Device Radii (Permeability Correction Factor = 0.3, Relative Humidity = 0.3, Ambient Temperature = 35 degrees Celsius, Turbulent Flow)).

So by increasing the area surface, the evaporation increases and according to that, the cooling effect increases too.

3. Conclusion

So if we put the pot-in-pot that is made out of earthenware with a good permeability in an area with low relative humidity and high velocity of wind and put it the way that the area available for evaporation exposes as much as possible, the device will work ideal. And the minimum temperature will reach by using these conditions and by using the temperature reader, we can determine the temperature and the minimum temperature that is reached is 4F.

WATER WAVES

Maryam Shahrami

A B S T R A C T

In this paper, oscillation of the horizontal cylinder on the surface of the water, vortexes and water waves that create on the surface were investigated. Till now in different articles, different shapes of the floater and Viscosity of the liquid has been studied. But In this article the parameters that depends on the cylinder`s shape, vortexes and some parameters like (frequency, amplitude and etc.) has been surveyed. In our experiments we saw that under certain conditions, the water waves drift away from or toward the floater (cylinder) and it was investigated.

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Keywords : *Cylinder, Amplitude, Frequency, Drift away, Circular path*

1. Introduction

As we told, when we generate water waves with a horizontal cylinder, different shapes of water waves and vortexes creates on the Surface of the water. You can see that the waves drift away or toward from the cylinder. In other articles they changed the geometrical parameters of the shape of the floater and viscosity of liquid and got some results.

Now we did some investigations and experiments to see what will happen and changed the parameters affecting on this phenomenon.

In fact Water waves are the waves having two types. "Gravity waves and Capillary waves".

Gravity waves are waves generated in a fluid medium or at the interface between two media when the force of gravity or buoyancy tries to restore equilibrium. An example of such an interface is that between the atmosphere and the ocean, which gives rise to wind waves. When a fluid element is displaced on an interface or internally to a region with a different density, gravity will try to restore it toward equilibrium, resulting in an oscillation about the equilibrium state or wave orbit.

A capillary wave is a wave traveling along the phase boundary of a fluid, whose dynamics are dominated by the effects of surface tension. Capillary waves are common in nature, and are often referred to as ripples. The wavelength of capillary waves in water is typically less than a few centimeters, with a speed of 10-20 centimeters/second.

Also other types of waves are "Faraday waves and Plane waves".

Faraday waves, also known as Faraday ripples, are nonlinear standing waves that appear on liquids enclosed by a vibrating receptacle.

Plane waves are constant-frequency waves whose wave fronts (surfaces of constant phase) are infinite parallel planes of constant peak-to-peak amplitude normal to the phase velocity vector. They are linear waves but when we change amplitude they change to non-linear 3D waves.

2. Methodology

Our solving method was doing some experiments and changing parameters that depend on this problem, like length of the cylinder, frequency, amplitude, viscosity of liquid, material of the cylinder, density of liquid, height of the water, diameter of the container and surface tension. Some parameters like viscosity of the liquid, material of the cylinder, density of liquid were constant.

The experiments setup was made of a big container (in diameter of 2meter) a cylinder and speaker used as a vibrator (Figs.1 & 2) and particles to see the direction of the waves.

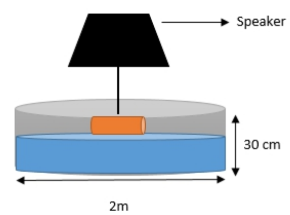


Fig.1: Experiments setup (Schematic)

Fig.2: Experiments set up

The effect of the diameter of the container is, if it doesn't be big enough the waves strike to the container's walls and it effects on waves not to be standing waves.

And the effect of containers height is that it is effective on waves. We distinguish between deep-water waves and shallow-water waves. The distinction between deep and shallow water waves has nothing to do with absolute water depth. It is determined by the ratio of the water's depth to the wavelength of the wave.

When the diameter of the cylinder changes, it's contact area with water changes and it is effective on the wave`s shapes.

Also the size and weight of the particles (Styrofoam) are important according to the amplitude and wave – length which they moved by (Fig. 3). Actually we need different amplitudes and frequency to move particles.

Fig.3: particles to show water waves

3. Results

3.1. The Theory of Direction of the Wave and Water Waves

As we said motion of the water is different than the motion of the wave. Water at each location moves in a circular path, but the motions at different locations are "out of phase", which means that when water at the left of the diagram is moving to the right, water a quarter of a wavelength to the right is moving down, and water next to it is moving to the left, and next to it is moving up, etc. (Figs. 4 & 5) .

Fig.4: Motion of the wave

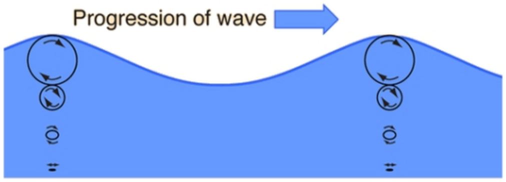


Fig.5: Difference between water’s motion and wave`s motion

The overall effect is an "apparent" wave moving to the right. Thus, the velocity (speed) of a wave is not at all the same as the velocity of the water.

The experimental wave shape is described as a "trochoid". A trochoid can be defined as the curve traced out by a point on a circle as the circle is rolled along a line (Fig.6).

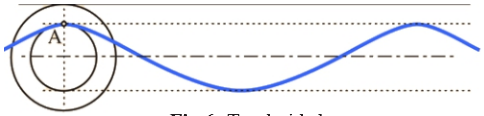


Fig.6: Trochoid shape

The discovery of the trochoidal shape came from the observation that particles in the water would execute a circular motion as a wave passed without significant net advance in their position.

The water molecules of a deep-water wave move in a circular orbit. The diameter of the orbit decreases with the distance from the surface (Fig. 7). The motion is felt down to a distance of approximately one wavelength, where the wave's energy becomes negligible.

The orbits of the molecules of shallow-water waves are more elliptical (Fig. 8).

The change from deep to shallow water waves occurs when the depth of the water, d, becomes less than one half of the wavelength of the wave, λ. When d is much greater than λ/2 we have a deep-water wave or a short wave. When *d* is much less than λ/2 we have a shallow-water wave or a long wave.

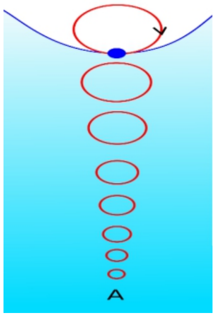


Fig.7: Water waves motion (deep water)

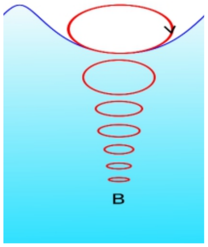


Fig.8: Water waves motion (shallow water)

Their wave speeds increase with wavelength, a behavior that is called "normal dispersion". For waves shorter than 1.73 cm, the surface tension of the water exerts a controlling force they are "capillary waves". Their speed increases as the wavelength gets shorter, a behavior that is called "anomalous dispersion". The minimum wave speed at wavelength 1.73 cm is 23.1 cm/s.

3.2. Results of the Experiments

We did experiments and changed some parameters. Parameters like amplitude, frequency, length of the cylinder. Also we changed the particles` size. And the number of these to know their movement better. Actually know the direction of the vortices.

In our experiments we understood that: Trajectories of fluid particles on the surface were described analytically only for progressing small amplitude planar waves, where particles move in the direction of wave propagation, along the prolate trochoid (Figs.9 &10) .

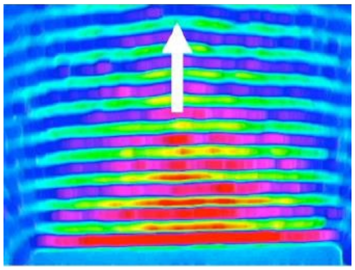
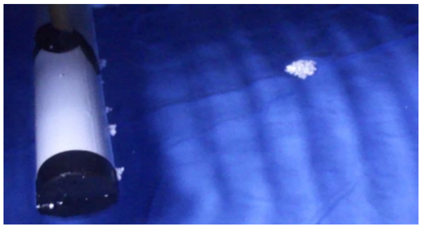


Fig.9: Plane waves (direction of wave propagation)



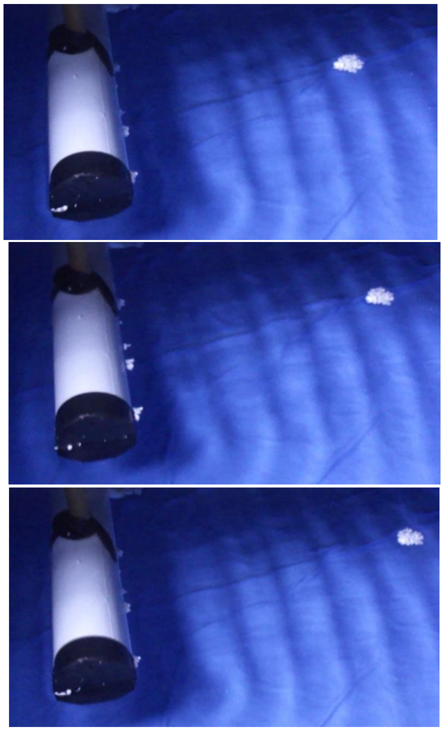


Fig.10: Moving particles in the direction of wave propagation

When we use an elongated cylinder, propagating waves have oval wave which fronts with long nearly planar parts for a cylinder, the wave fronts are modulated even at relativity low amplitude.

The maximum of the wave amplitude is at the center of the cylinder side here, floating particles are pushed in the direction of the wave propagation forming strong outward jet (Fig.11).

Water Waves (35-38)

Fig.11: maximum of the wave amplitude

The flow changes dramatically when the wave amplitude is increased above the modulation. Instability threshold at only 20-30% higher acceleration of the wave maker (cylinder).As the modulation grows and the cross wave instability breaks the wave front into the trains of propagating wave pulses, the wave field becomes 3D (Fig.12).

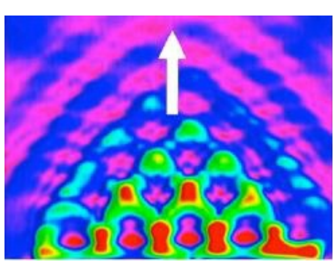


Fig.12: As the wave maker acceleration is increased (30%) the modulation instability destroys the wave planarity generating 3Dwave field shown here

Simultaneously, the direction of the central jet reverses. It now pushes floaters inward, towards the wave maker and against the wave propagation! The flow is strong enough to move small objects on the water surface, for example a ping pong ball or Styrofoam (Fig.13).

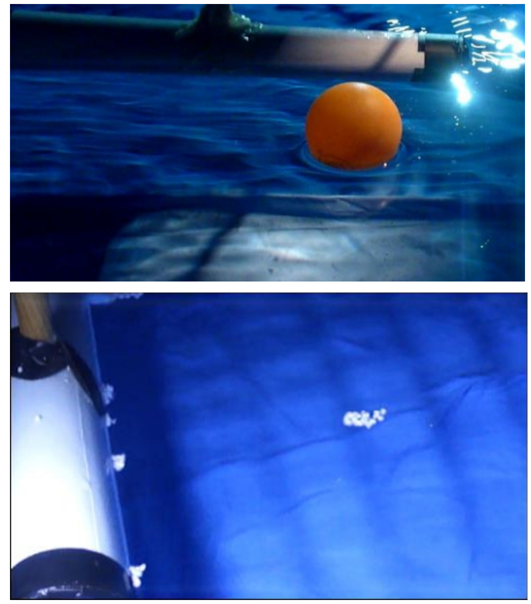


Fig.13: The flow is strong enough to move small objects on the water surface

We find that these waves are produced by the nonlinear 3D waves in the range from long gravity waves (8Hz) to short capillary waves (50Hz).

A quadruple pattern made of 4 large counter-rotating vortices . A quadruple pattern is formed around the cylinder made of 4counter-rotating vortices. Two jets develop in the direction away from the wave maker (Fig.14).

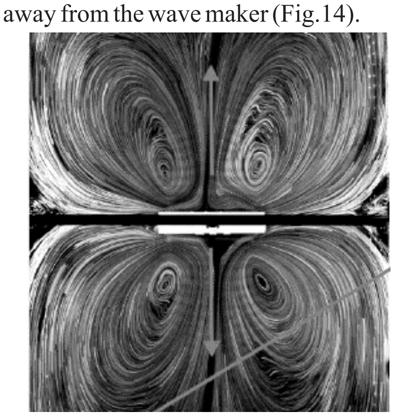


Fig.14: A quadruple pattern is formed around the cylinder made of 4counter-rotating vortices. Two jets develop in the direction away from the wave maker

The direction of the vortex rotation however reverses with the increase of modulation .This reversal at higher wave amplitudes is always correlated with the generation of stochastic Lagrangian trajectories within a flow region in front of the wave maker (Fig.14) .This complex chaotic flow efficiently transports fluid in the direction perpendicular to the propagation of the wave pulses.

Also after specific amplitude, particles absorb to the cylinder. Actually at higher amplitudes particles absorb to the cylinder and at lower amplitudes they drift away the cylinder. In fact we can say that the frequency moves the waves in their direction but amplitude changes their direction.

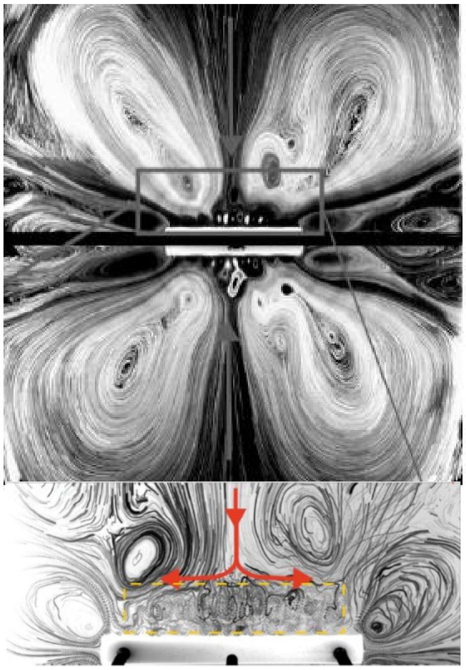


Fig.14 : Particle streaks in the vicinity of the cylindrical wave maker visualize a region of Lagrangian stochastic transport (yellow dashed box).Turbulence pumps particles away in the direction of red arrows, orthogonal to the wave propagation

Frequency is independent of the movement of the particles (direction of the wave`s movement. After specific frequency we cannot have the same amplitude like before, because of the Inertia force of the speaker. And we can`t see the changes in the direction of the waves after this.
It means that when we increase the frequency, amplitude decreases.

4. Conclusion

The investigation was about the surface waves creating on the water that they create by a cylinder. Our method were doing experiments. And we changed some parameter like amplitude, frequency, length of the cylinder etc.
A particle moving in a circular way, but it doesn't have a vector the same as other particles (actually the molecules doesn't traverse same ways).so it causes the move in different ways.

If the amplitude and frequency be constant the water molecules Travers their circular way completely, but when we increase them their speed goes up and they don't have time to travers all the way and as a result we see that they go up and down and throw out and get different shapes.
We understood that frequency isn't effective on the drifting away of the waves and it's the effect of amplitude . Also the direction of molecules movement depends on the depth of the water.

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SIREN

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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.

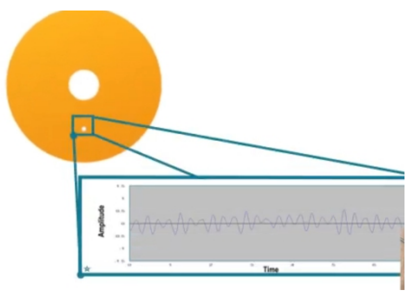


Fig.1: The amplitude of the sound hearing from the disk (Schematic)

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.

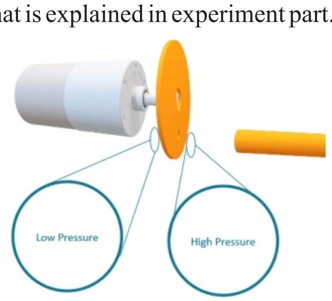


Fig.2: Pressure difference in this phenomenon

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).

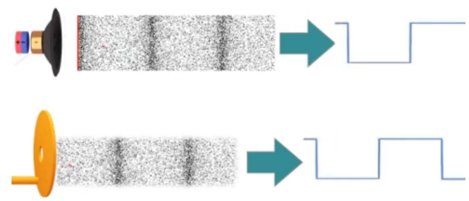


Fig.3: Disk and speaker comparison

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).

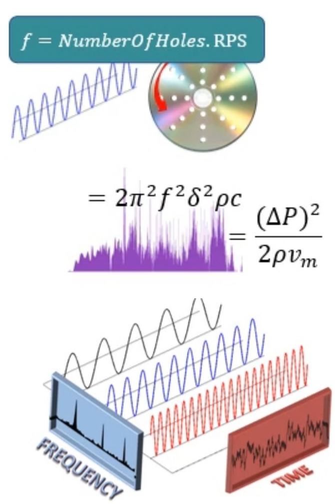


Fig. 4: Frequency vs Time

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).

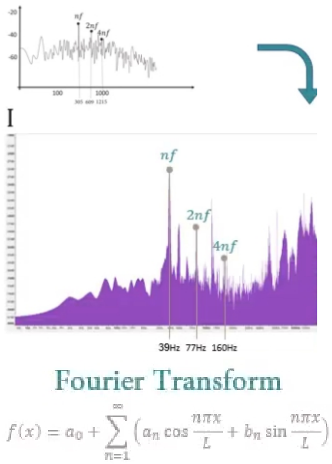
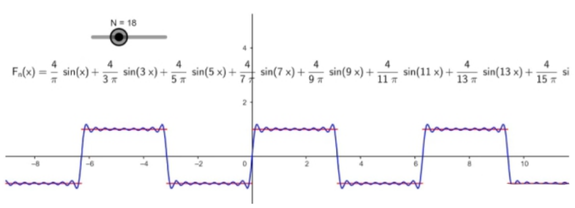


Fig. 5: Fourier series

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.

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

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

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

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).

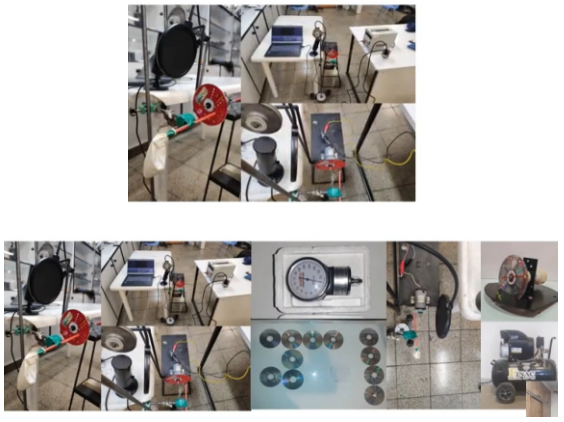


Fig. 6: Experimental Setup

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).

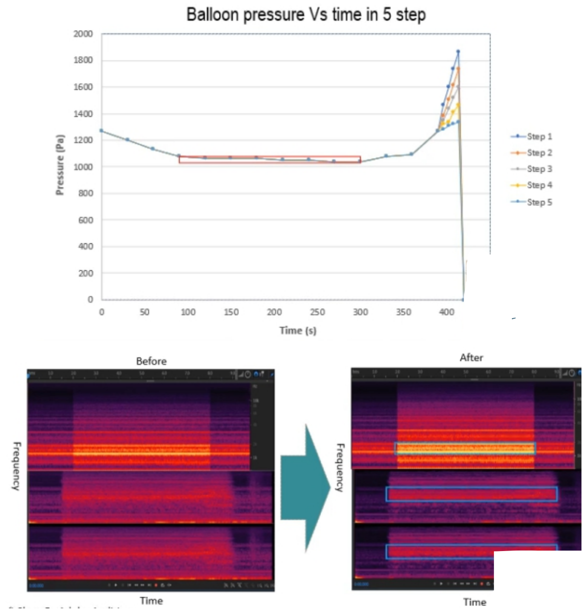


Fig. 7: Frequency in different steps

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.

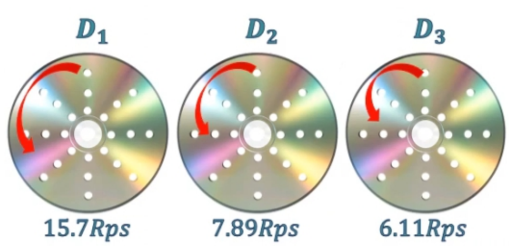


Fig. 8: the RPS of each frequency

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
D2	7.9	126.24 Hz	Voice 2
D3	6.1	97.76 Hz	Voice 3

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

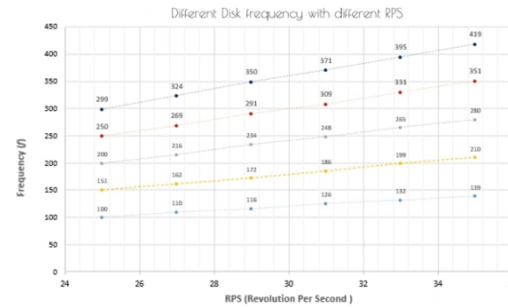


Fig. 9: Different frequencies

"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).

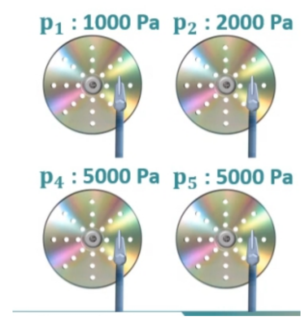


Fig. 10: Experiment in different pressures

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.

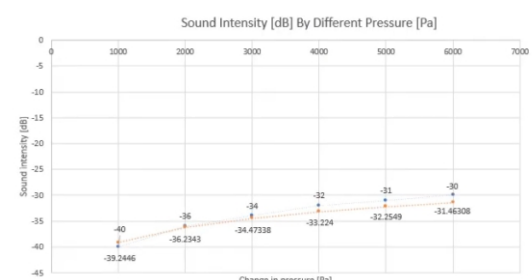


Fig. 11: Sound intensity in different pressures

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

$$f_1 = f_2 = f_3$$
$$I_1 < I_2 < I_3$$

$$\mathrm{I} = \frac{(\Delta P)^2}{2\rho v_m}$$

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).

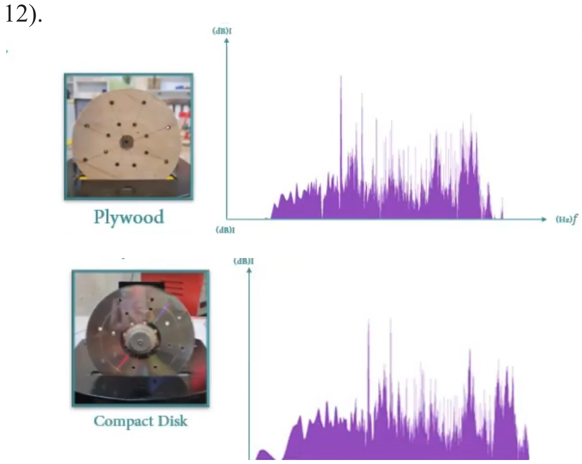


Fig. 12: Comparing two different materials

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).

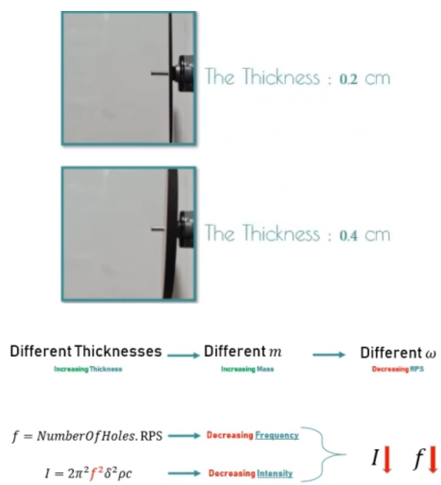
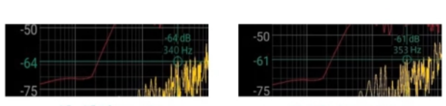


Fig. 13: Different frequencies in diffferent thicknesses

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.



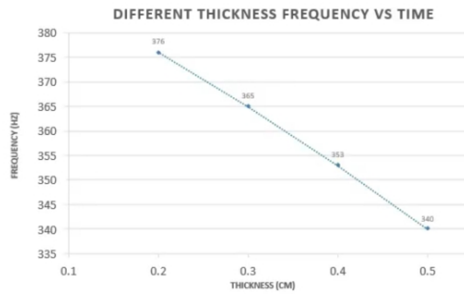


Fig. 14: Frequency VS time in different thicknesses

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).

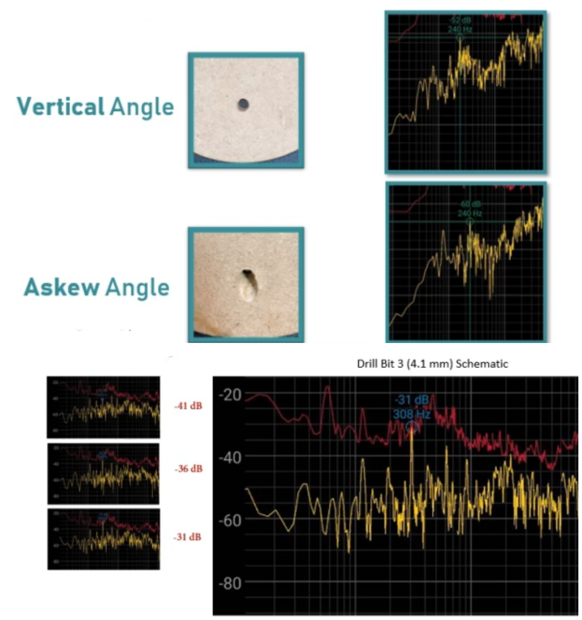


Fig. 15: Different angles

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).

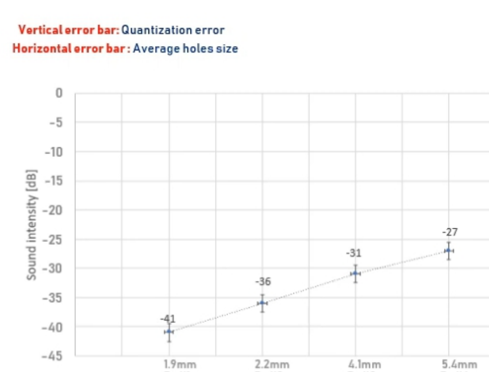


Fig. 16: Different sizes of the holes

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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