Resonating Glass

Mahdiyeh Shahrabi Farahani[a] *, Ida Rasouli Astani* [b]
* *Corresponding Authors :* [a]*m.shahrabi426@gmail.com,* [b]*ayda.rasouli@yahoo.com*
School: [a]*Elham school,*[b]*Farzanegan 3*

Abstract

To investigate how the resonance of a glass partially filled with liquid depends on various parameters when it exposed to the sound from a loudspeaker our experiments have been done. It is well known that the pitch of the sound produced by an excited glass shell can be tuned by adding some liquid in it. This investigation is approached through recording the frequencies due to change each parameters by two different methods. The PC software tool FFT – Properties was used to calculate the frequency . Also NCH Tone Generator software was used to produce the sound with a constant frequency. In other method microphone was placed approximately 2 cm below the glass rim and at a distance of about 2 mm from the glass. Then by hitting the glass and recording the sound, the natural frequency of glass was found by MATLAB . By analyzing the theories and results of testing, we concluded the intensity and frequency of sound affect on the resonance of glass . Also volume and density of liquid which is poured in glass, have influence on this phenomenon. The intensity and frequency of sound has a direct relationship with the resonant frequency of the glass but volume and density of liquid and the glass resonant frequency are related inversely with each other.

Introduction

By rubbing your moistened finger around the rim of a water glass besides enjoying a generally rather pure tone emitted by your singing glass, you might even take pleasure in observing some ripples on the liquid surface that follow your rotating finger. On a less playful level, many famous composers such as Mozart, Berlioz, or Saint-Saëns have written master music pieces for instruments based on glass vibrations, also called "musical glasses". Unlike materials such as quartz or iron, the molecules in glass are arranged in an amorphous structure rather than a crystal. The lack of a crystal lattice structure makes glass very brittle, and it shatters via a conchoidal fracture that does not exhibit planes of separation. Most ordinary glasses used in windows and jars are soda-lime glasses, while many drinking glasses are made from borosilicate glass to protect them from the thermal strain of hot beverages. Force exerted by the finger is rich in harmonics only the fundamental component match the frequency of vibrational mode despite the bowing with violin bow and stick slip mechanism whose mode frequency are harmonically related . Most glasses will contain microscopic cracks that serve as the seed crack from the fracture. For a thin sheet of material in a glass, the weak material properties of glass substantially ease the ability of sound pressure waves to meet the energy threshold of a fracture.

The vibrations of a glass which is in front of a speaker vibrate the air molecules and continue their propagation by vibrating the molecules of glass wall .When they pass the glass wall, continue their vibration by shuddering the molecules of the liquid that is poured in the glass. But what happens when the sound waves arrive to the end of the first environment (the border between the two environments). Actually some of the waves pass the common border between the two environments and enter the second environment and rest of them are reflected from the common border and return the first environment. When the energy is applied to the glass, it will be vibrated at its natural frequency. The main approach in this research is measuring the resonant frequency of glass in different conditions.

Theory and Experiments

When waves travel towards each other, instead of breaking the rhythm totally, they travel through each other. There are two types of superposition, constructive, where the net sum of the waves gives a positive displacement, and destructive, vice versa. When the sound source is speaker, the sound waves are distributed in spherical form. This kind of source distribute waves in the form of concentric spheres (The center of all the waves is from the source) around its space. When the waves get away from their source, the energy of sound will be distributed on a larger surfaces of radius r . If the power of the produced waves is constant, then wave intensity will be proportional to the inverse square of the distance from the source. So if we double the distance between a point and sound source , the sound intensity will be a quarter of the first case (Fig. 1).

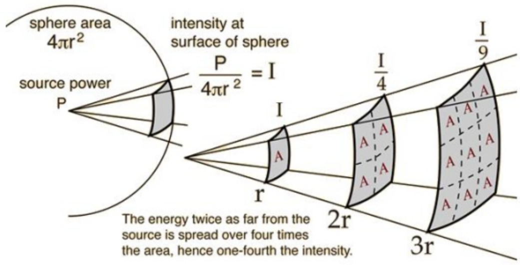


Fig. 1: the relationship between the sound intensity and wave area,
http://whatmusicreallyis.com/research/cymatics/

A rigorous treatment of the vibration of liquid-loaded glasses is a complex matter for several reasons. Even for an empty glass, the profile is not simple and is different for every glass type. In addition, the wall thickness varies progressively from relatively thick at the base to thin at the top edges (Fig. 2a). In vibrating glasses the fundamental mode distorts the circular rim into an ellipse (Fig. 2b). A solution for mode shape and frequency could, of course ,be obtained for an arbitrarily shaped partly filled glass by using finite-element numerical analysis, but this would lead to specific rather than general understanding.

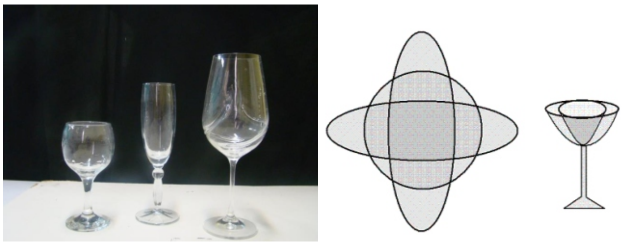


Fig. 2: a) several types of glasses, b) how vibration makes distorting in glass

The experimental setup consists of 3 types of glasses, some liquids such as Honey ,Water Glycerin ,something to hit glass which doesn't make sound itself and of course should be something doesn't add obtrusive frequency and also NCH Tone Generator software was used to produce the sound with a constant frequency (Fig. 3).

Fig. 3: Experimental setup

The frequency of a simple harmonic motion like a mass on a spring is determined by the mass m and the stiffness of the spring expressed in terms of a spring constant k (Hooke's Law) (Fig. 4).

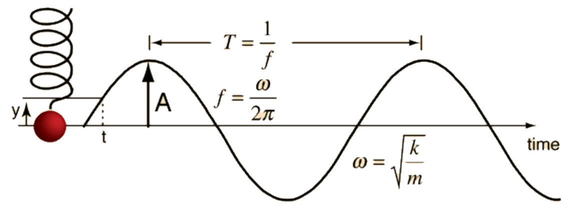


Fig. 4: Simple harmonic motion

f_0= frequency of empty glass
f_d= frequency of partially filled glass (Hz)
β = a constant
ρ_l = density of liquid
ρ_g= density of glass
R = radius of water
a = glass thickness
d = distance from top of glass top water
H^*= effective height of glass

$$\left(\frac{f_0}{f_d}\right)^2 \approx 1 + \frac{\beta \rho_l R}{5 \rho_g a}\left(1 - \frac{d}{H^*}\right)^4 \qquad (1)$$

$$\left(\frac{f_0}{f_d}\right)^2 = 1 + kX^4 \qquad (2)$$

For visualizing glass vibration , the laser beam was used (Fig.5).

Fig. 5: Detection glass vibration by laser

In the first experiment the frequency of the glass filled with different liquids were investigated.

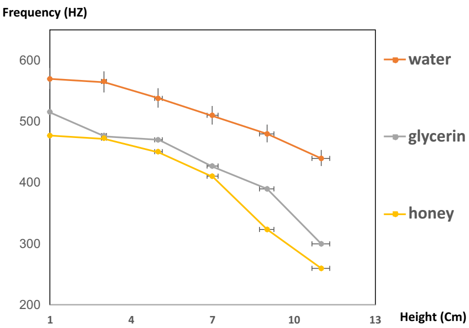


Fig. 6 : Frequency of glass with different liquids

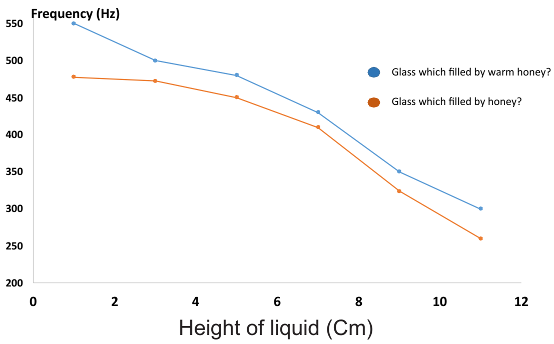
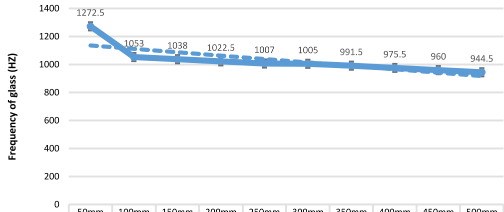


Fig. 7: Frequency of glass with honey but in different temperatures

The power of the sound is steady and we changed the area by changing the distance between the speaker and the glass to investigate the effect of sound intensity on the resonant frequency of the l glass (Fig. 8).



	50mm	100mm	150mm	200mm	250mm	300mm	350mm	400mm	450mm	500mm
Avrage	1272.5	1053	1038	1022.5	1007	1005	991.5	975.5	960	944.5

Fig. 8: t frequencies of the glass in different distances

The relationship between the sound intensity and the area was investigated too (Fig. 9).

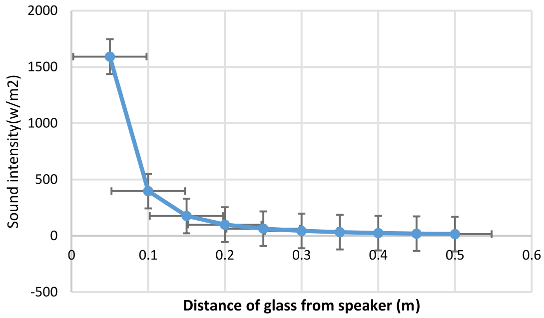


Fig. 9: sound intensity in different distances of the glass

When a wave passes the environment, in dealing with it, vibrate its first particle. After that, that particle starts to vibrate the nearest bit to itself with the same frequency which it has received from the wave. So that transferring the energy of the sound will be done by transferring the energy of the sound will be done by transferring the wave frequency to every single bits of environment. In high-frequency the number of vibrations per second is much more than the low-frequency sound. Thus, we can conclude that high-frequency waves transfer more energy than the low-frequency sound. In other experiment we have investigated the effect of frequency of played sound on resonant frequency of glass by changing the frequency of sound (Fig. 10).

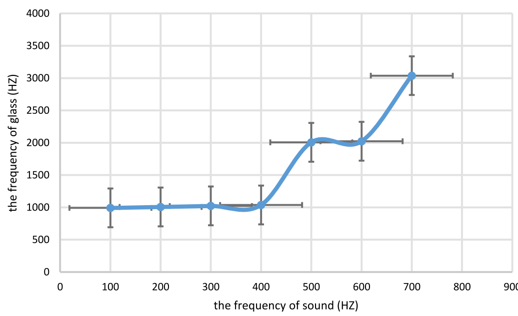
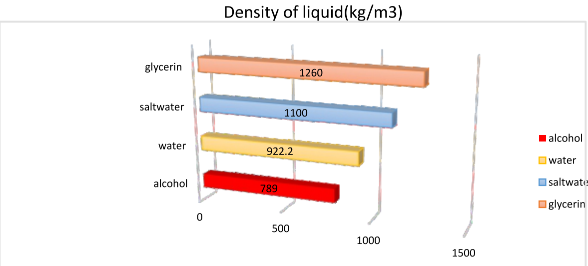


Fig. 10: frequency o the glass in different speaker frequencies

The effect of liquid density on resonant frequency was investigated by four kind of liquids with different densities, water, dense salt water, glycerin and alcohol (Fig.11).



	alcohol	water	saltwater	glycerin
Density of liquid(kg/m3)	789	922.2	1100	1260

Fig. 11: frequency o the glass in different densities of liquid

The relation between the frequency of glass and depth of liquid was investigated too. First of all we found small amounts of liquid do not significantly change the pitch level. Thus, the pitch is nearly constant at about 1395 Hz as the glass is filled up to the quarter of its total height, i.e. about 4 cm. As more and more water is poured into the glass, its effect on the pitch lowering is more important. It decreases regularly and significantly down to 703 Hz as more liquid is added into the glass shell (Fig. 12).

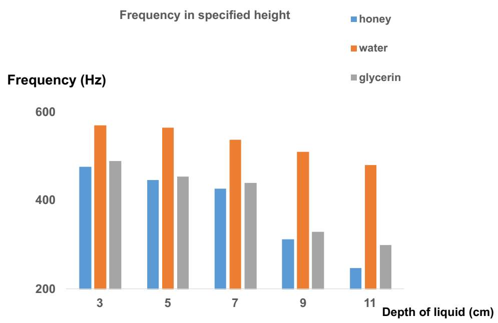


Fig. 12: frequency of the glass in different depth compared in different liquids

Conclusion

According to the experiments and the theories, the following conclusions can be reached:

-Sound intensity and its frequency have a direct relationship with the resonant frequency of the glass which means by increasing these parameters, resonant frequency of the glass will increase too.

-The lowering effect of the liquid is simply due to the added vibrating mass in the glass–liquid system as mentioned earlier. In order to understand the increasing effect of water on the pitch level as more and more liquid is added, it is necessary to take into account the vibrating profile of the shell. Since the bottom of the shell cylinder is clamped, its vibration is very small in the lower part of the glass inducing negligible oscillations in the liquid.

As the water reaches higher heights, it comes into contact with parts of the shell which vibrate with larger amplitudes Therefore, the upper part of the liquid contributes more significantly energy of the liquid–glass system. Indeed, the frequency shift versus the liquid level in the glass shell is very sensitive to the vibrating mode profile. The frequency of the sound is plotted versus the upper water level reached for various initial amounts of water in the glass. From any initial resting amount of water, the rotation of the liquid clearly lowers the pitch level by a significant amount. For instance, a glass filled with an initial level of h = 10 cm has a pitch level of 800 Hz.

-Experiments give evidence of ,if liquid has more viscosity it has less frequency and deeper tone but of course natural frequency of glass changed from specified height , the part of glass which filled by liquid doesn't vibrate as quickly as the part which doesn't filled by any liquid .

-The results clearly confirm the weak contribution of the central part of the liquid because of the decaying radial amplitude of the vibration. Although our simple model permits us to give a good description of the observed influence of the cylinder on the pitch lowering, it cannot explain the small differences measured for each cylinder.

-The presence of a liquid does not change the vibrational structure of a singing water glass in a first approximation in spite of the obvious lowering of the resonance frequency, i.e., the vibrational movement of the glass continues nearly undisturbed below the level of the liquid. A more detailed analysis of our experimental results reveals, however, that the nodal line becomes modified near the glass rim: using time-average holographic interferometry, however, in the case of immersed cylinders, the acoustic impedance must be taken into account for a more accurate analysis. The additional pressure on the glass shell induced by the lateral liquid flow is not negligible any more. Although all liquids have less viscosity like water change natural frequency from specified height and some liquids which has more viscosity like honey , glycerin change natural frequency from the first, but we can say all liquids in glass are like damper in spring that is reason why liquids change frequency. That's one of the parameters influences on resonance of glass. The other parameters are shape of glass , glass thickness, density of liquid, radius of the bowl, rim of the glass and height of the stem of glass.

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