Final Group Project 1 Image: Faraday waves in water excited at a frequency of 8 Hz.

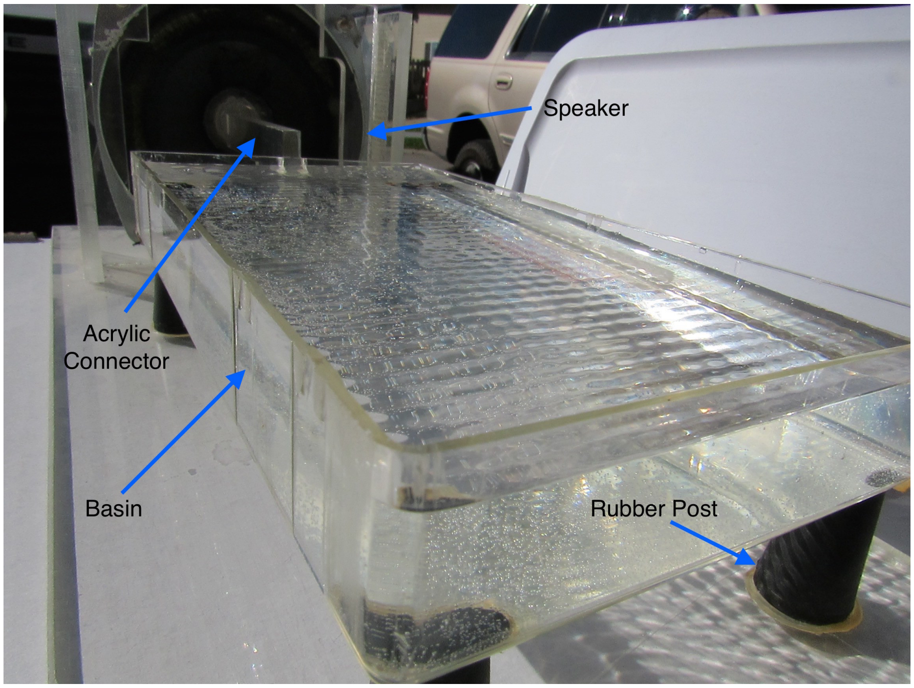
1 Purpose

This visualization is a part of the first Flow Visualization group project. The purpose of this visualization was to capture the capillary wave, or ripple, phenomena produced when water is perturbed. This is a very common occurrence, as can be seen in ponds and lakes when a heavy gust of wind blows over, or when a person walks into the water causing ripples to spread out all around them. The specific type of capillary wave captured in this project is a Faraday wave, which is classified by its nature of being a nonlinear standing wave when excited by a certain frequency in a vibrating enclosure. The photo was achieved thanks to the help of Scott Kittelman of ATOC, who let our team borrow and use the capillary wave setup.

2 Flow Apparatus

The enclosure used to achieve this visualization is composed of a rectangular acrylic basin that is roughly 8inx4in across, and about 1 inch in depth, which is mounted on top of 4 rubber posts. These posts allow for the movement of the basin when it is excited by different frequencies, since a rigid post would not as easily transmit motion from the vibration that is exciting the fluid. The manner by which the frequencies are transferred to the basin is through a rectangular acrylic piece that is in contact with one side of the basin, while the other end of the piece is attached to a small speaker that can transmit the generated frequencies. The speaker was driven by a wave generator and amplifier. An image of the apparatus is shown below.

These standing waves that appear in the fluid occur at specific frequencies, known as the resonant frequency. The resonant frequency occurs when waves being generated are reflected back and forth within the basin with their peaks occuring at the same locations. In general, the Faraday waves can appear in a square, striped, or hexagonal patterns, depending on the frequencies that the apparatus is being resonated at.



Capillary wave apparatus

3 Flow Technique

The basic flow that is happening in the flow visualization image is the lateral excitation of the water in the basin by the frequency coming from the wave generator. The wave that was generated was a sine wave, and the particular frequency that the image was taken at was around 8Hz. Different resonant frequencies were achieved building up to 8Hz., each producing different shapes in the water.

The ability of the standing waves to form depends on a few factors. As discussed by [2], the formation of the standing wave depends on the viscosity of the fluid, the surface height of the fluid, and frequency of oscillation. The capillary wave generator was filled about 3/4 full with tap water. The viscosity of water is $1.002 mPa * s$ at 20°C, and will decrease with increasing temperature. This is true for liquids in general, and can be directly observed when oil becomes more fluid after being heated in a pan. With regard to the capillary wave generator, fluids with low viscosities are better suited for observing the standing wave phenomena since the fluid is dynamically more susceptible to movement when excited. The temperature on October 14th was about 20°C, and so the viscosity was the same as was listed above.

It can be seen in the final image that the lateral movement of the basin generates waves that propagate in the direction of the forcing, but the collision of the waves with the basin also causes interferences normal to those waves to occur. This specific resonant frequency is generating standing waves that form a type of circular shape, which can be seen very clearly toward the top of the final image.

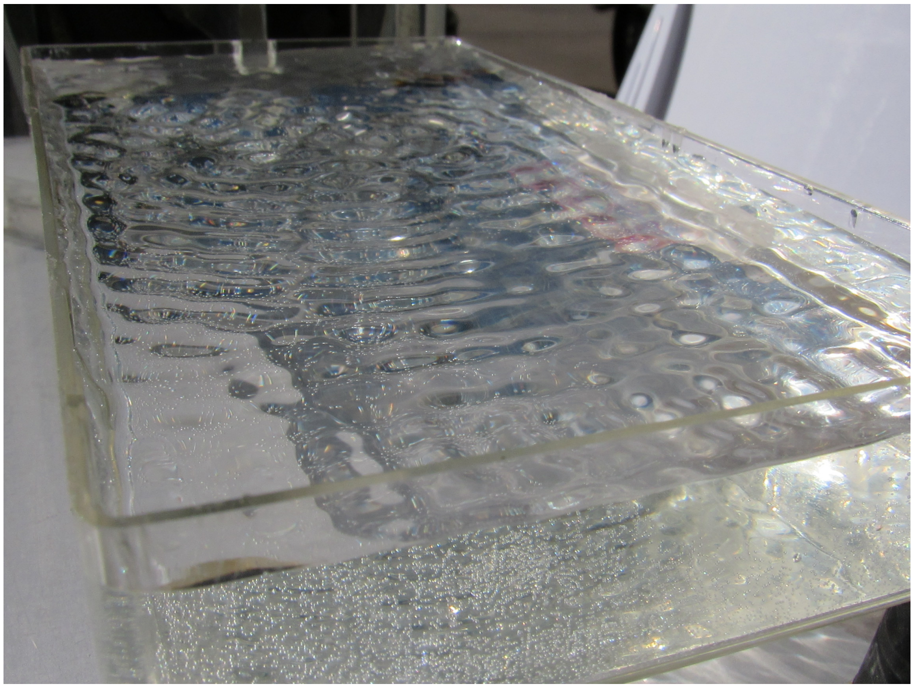
4 Photographic Techniques

The technique used to capture this image is an index of refraction technique, which utilizes the air-water boundary and the light that is reflected off of the surface of the water to capture the fluid structure being created. The light used to create this effect is from the sun, and this image was taken at 10:45am on October 14th. The sunlight apparent on the surface of the water refracted beyond the surface of the water creates a lensing effect in the bubbles in the water, reflecting a variety of colors below the standing waves.

The surface of the water was approximately 5 inches away from the camera lens, while the focal length was 7.242mm. The digital camera that was used to perform this visualization is a Canon PowerShot SX520 HS, with a focal length of 4.3-180.6mm, aperture 1:3.4-6.0. The settings used to capture the image are as follows:

- Shutter speed 1/1600
- f/8
- ISO 200

The original image size was 2304x1728 pixels, while the final was 1317x876 pixels. GIMP was used as the choice of image editing software, where post processing was performed to enhance the blue in the surface of the water, and brighten the whites in other areas. This was achieved using the Curves feature by creating an "S" shaped curve. Some cropping was done to zoom into a section of the standing waves, and get rid of the appearance of the surrounding container. The original image is displayed below.



Original Image

5 Image Thoughts

This image reveals the overlapping waves generated by the speaker at 8Hz. It also shows the susceptibility of water to the vibrations it is excited by. If I were to do this project again, I would have taken a larger range of photos from different angles and attempted to perform shadowgraphy to capture the shadows of the standing waves to more clearly visualize the patterns in the waves. Also, a high speed video would be a very interesting visualization, and a camera with a high enough frame rate could potentially capture the interference of the waves as they are passing through the container.

References

[1] Nave, R. *Standing Waves.* Georgia State University. `http://hyperphysics.phy-astr.gsu.edu/hbase/waves/standw.html` Accessed on: 4 Nov., 2015.

[2] Bailey, David. et. al. *FAR: Faraday Waves and Oscillons.* (2014): University of Toronto. `http://www.physics.utoronto.ca/~phy326/far/far.pdf` Accessed on: 6 Nov., 2015