Standing Waves at 26 Hz in a Circular Dish

Wayne Russell

MCEN 5200: Flow Visualization

Prof. Jean Hertzberg

As an introduction to flow visualization, this assignment required an image of any type of fluid flow. The image discussed here shows standing waves on the surface of water in a circular dish. Interesting patterns developed when the dish was vibrated at several frequencies between 20-35 Hz, but the pattern associated with a 26 Hz excitement frequency was particularly unique. The patterns are created in a process similar to Faraday waves; the instability develops rapidly due to a vertical vibration. Balsamic vinegar was used to dye the water, allowing the reflections of the light off the surface to be captured.

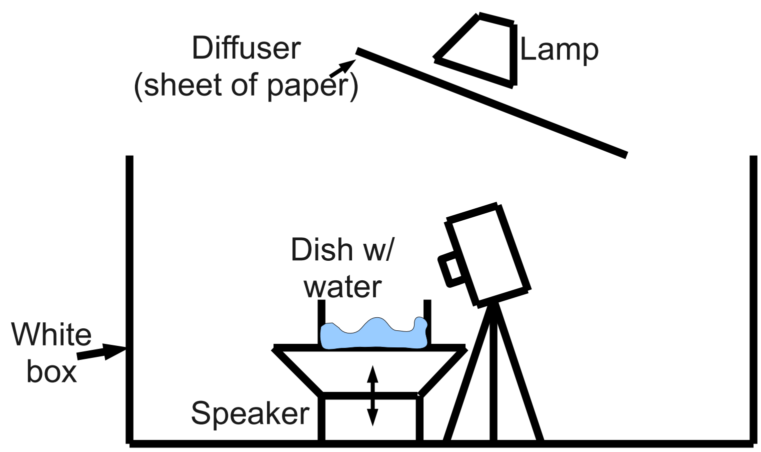

Figure 1: A dish of water was placed on top of a vertically oscillating speaker in a white box to capture the image.

In order to generate the standing waves, a single speaker was used. It was positioned such that the vibrations created a vertical motion. A conical glass dish with a diameter of 8.1 cm at the bottom and 8.7 cm at the top and height of 4.1 cm was filled to a height of 1.7 cm with water. To add color, two tablespoon of balsamic vinegar were added to the water. A 26 Hz sinusoidal waveform was generated using Jaaa, an open-source audio software analysis tool. The camera was positioned 6 cm from the surface of the water using a small tripod. The apparatus is shown in Figure 2.

Steady vibrations will cause waves to develop on the surface of an incompressible fluid. In a small container, these waves will reflect off the wall, causing unique patterns to form. When the instability is caused by vertical vibrations, the patterns are known as Faraday waves[1]. Faraday waves oscillate at a frequency that is half that of the excitation frequency[2]. The size and shape of the container, depth of the fluid, surface tension, and viscosity all play a role in the amplitude and shape of the standing waves.

In an ideal Faraday wave, the wavelength can be determined from the relation

$$g_*(1+k_*^2)=1 \quad (1)$$

where $g_*=\frac{gk}{\omega^2}$, $k_*=k\sqrt{\frac{\alpha}{\rho g}}$, α is the surface tension (72.8 dynes/cm for water), ρ is the density (1 g/cm^3 for water), ω is half of the excitation frequency, *g* is the gravitational constant (in cm/s^2) and *k* is the wave number[3]. The properties of vinegar were not taken into consideration due to the small amount used. Using an iterative solving method, the wave number can be found to be roughly equal to 1 cm.This means there are roughly 8 full wavelengths in the image. Dividing the image into 8 parts across the length or width does show some symmetry (for instance, each of the four "arms" in the cross are roughly one wavelength in length).

In order to capture the image, 9 mL of water was placed in a dish. Two tablespoons of balsamic vinegar were added to the water, allowing the colorful reflections to be captured. The dish rested on top of a speaker in a box lined with white paper. A 10 W compact flourescent light bulb was placed 40 cm from the dish. A sheet of printer paper was held 10 cm from the light bulb in order to act as a diffuser. No flash was used.

The camera used was a Canon Powershot ELPH 300 HS, a point-and-shoot digital camera. The surface of the water was about 6 cm from the lens of the camera. In order to capture a clear image without blur due to the motion of the water, a relatively high shutter speed was used, 1/500. Due to the short integration time, the ISO was fairly high: 4000. This introduced some noise to the image, but also prevented motion blur. The blur and smudge tools were used in Gimp to reduce the noise in the image. Additionally, the contrast was adjusted to enhance the shadows in the image. The red channel was specifically manipulated to add more color to the image and bring out the orange band around the top. The original image was 4000x2248 pixels, the cropped image is 3159x2248 pixels.

This image shows an interesting flow pattern. Standing waves often develop concentric circles, so the appearance of a cross shape is unique. The dark reflection of the camera on the bottom edges of the standing wave also adds an eye-catching effect. The complicated flow in the small dish is captured clearly and can be analyzed based upon the image and dimensions, although determining the amplitdue of the waves is difficult. The speaker was not firmly attached to any solid surface, doing so may have provided larger amplitude waves. Using more uniform and brighter lighting would have allowed a lower ISO setting to be used, reducing the noise. All-in-all, this is an interesting image that can be used to do some degree of scientific analysis as well.

References

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[3] D. Binks and W. van de Water, Phys. Rev. Letters **78,** 4043 (1997).