Coiling Instability in Honey

Image-Video 2

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Introduction:

For the second image-video assignment, the goal was again to take a picture or video that demonstrates a phenomenon being observed and is a good picture or video. The phenomenon shown in this image is the coiling instability of honey. To visualize this phenomenon, a picture was taken to capture honey squeezed from a bottle into a jar filled with more honey.

Physics and Flow:

The flow apparatus used in the image is demonstrated in figure 1. An empty jar was first filled with honey two inches from the bottom and honey from a bottle was squeezed into the jar roughly two inches from the top of the jar.

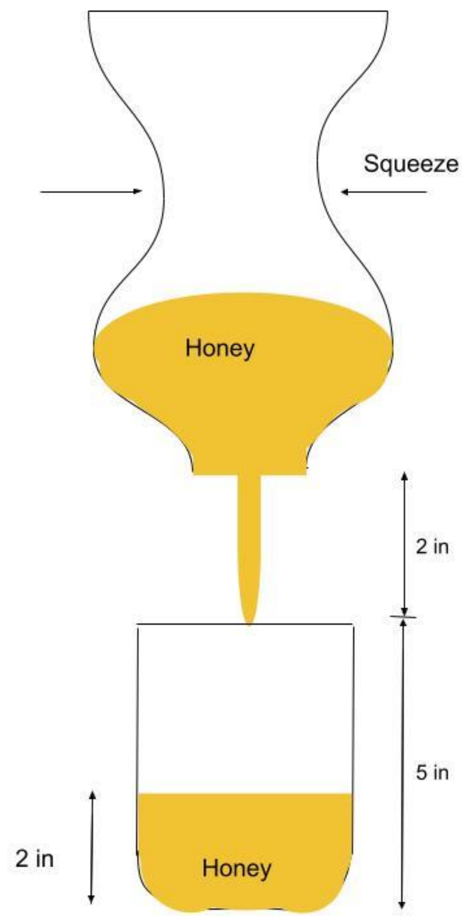

Figure 1: Sketch of Honey Squeezed into Jar of Honey

The phenomenon occurring here is known as the coiling instability which also has many other instabilities tied to it. The first noticeable instability is buckling which is "the transition from a straight to a bent configuration due to the application of a load." [3] This instability mainly occurs in solid mechanics, however, because the viscosity of honey is so high, buckling was able to occur here and in other highly viscous fluids. It was also discovered that if the speed at which the honey was squeezed out of the bottle was small, liquid folding would occur instead of liquid coiling. This is still considered buckling, but instead of the honey curling into a coil, the honey would fold like a sheet.

To theoretically measure how the coiling instability applies to honey, the coiling frequency formula can be applied. The formula is defined as $f = \left(\frac{Q^4}{v}\right)^{\frac{1}{3}} * H^{3.3}$ [4] where f is the coiling frequency, Q is flux, v is viscosity, and H is height. The viscosity of honey is $1140.8 \left(\frac{in^2}{s}\right)$ [1] and the height is roughly 5 inches based on figure 1 where the height of the jar is subtracted by the height of the honey in the jar added with the height of which the honey is being poured from. It was determined from the experiment that the amount of honey transferred from the 0.3 inch opening of the bottle filled the jar approximately 0.2 inches in roughly 8 seconds. The radius of the jar is also 1.58 inches. The density of honey is also $0.05 \frac{lb}{in^3}$. The volume (1), flux (2) [2], and coiling frequency (3) are found below.

$$V = \pi r^2 * h$$
$$V = \pi(1.58^2) * 0.2 \qquad (1)$$
$$V = 1.57\ in^3$$

$$Q = \frac{\rho V}{\pi * r^2 * t}$$
$$Q = 0.05 * \frac{1.57}{\pi * 0.2^2 * 8} \qquad (2)$$
$$Q = 0.078\ \frac{lb}{in^2 * s}$$

$$f = \left(\frac{Q^4}{v}\right)^{\frac{1}{3}} * H^{3.3}$$
$$f = \left(\frac{0.078^4}{1140.8}\right)^{\frac{1}{3}} * 5^{3.3} \qquad (3)$$
$$\boxed{f = 0.65\ Hz}$$

Based on the set up of the experiment, the main variable contributing to the coiling frequency of the honey is the height. In general, the coiling frequency will increase nonlinearly as the height at which the honey is poured increases.

Visualization Technique:

The visualization technique used was squeezing a bottle of raw, unfiltered honey into a jar of the exact same honey. The jar was a clear jar that was 5 inches in height and an average of 3.15 inches in diameter. The jar was placed onto white fabric which was also used as the background and was filled with two inches of honey. Before taking a picture, the lights were completely off, and the photo was taken at night so no sunlight would interfere with making the scenario pitch black. A laptop was used as the main light source by finding a video of a completely white screen and turning the brightness up to light the jar as much as possible. The laptop was placed to the left of the cup. A light ring was also used to light the scenario up even more. The light ring was placed in front of the jar.

Photographic Technique

Like the first image-video project, the field of view was one of the first techniques considered. Since the thickness of the honey and the coiling was very small within the jar, the distance from the jar to the camera lens was around 2 to 3 inches away. This way, any distractions around the jar would be cut out so that the honey would act as the main center of attention for viewers. Once again, zooming in was not ideal because it would blur the image quite a bit. The camera and settings were as followed:

Camera:	Samsung Galaxy S9
Aperture:	f/1.5
Exposure:	1/500s
Focal Length:	4.3 mm
ISO:	800
Width:	4032 pixels
Height:	3024 pixels

The type of camera was a phone camera because it was convenient and still had decent picture-taking capabilities. The aperture was set to f/1.5 to allow more exposure to light since the picture was being taken in the dark. Any light apart from the light from the computer and light ring gave the photo an unbalance in color, so all external lights and flashes were turned off. The exposure was set to 1/500 to capture the coiling of the honey. The coiling would not last very long and would diminish within a second. Since the experiment was conducted alone, a higher exposure made up for the inconsistencies in squeezing the bottle and the short duration of the coiling. The focal length was set to 4.3 mm to put the coiling of the honey in focus. The ISO was set to 800 to allow more sensitivity to light to make the picture brighter. The laptop light and ring light were bright enough to be able to increase the exposure as well. Lastly, the final image width and height were 4032 and 304 pixels respectively. This width and height were the best setting for the Galaxy S9 because it allowed it to take a 12 MP picture which was the highest it was capable of.

For post-processing, the shadow and shading of the photo were fixed so that more focus could be on the honey. The original photo was a lot wider and had a lot more distractions that involved light and items outside of the jar. The honey was also sharpened to make up for any blurriness and the color of the honey and background were slightly adjusted to make the honey more distinct.

Conclusion:

The image showed the coiling instability honey being poured from a bottle into a jar of the same honey. The way the honey would perfectly spiral and curl onto itself was very interesting to me. Although this phenomenon did not occur constantly, it was very intriguing and awe-inspiring to me when I was able to capture the moment it would coil. This phenomenon also shows how viscous honey is compared to liquids like water or milk which would not have the same solid mechanical properties. Something I did not like about the image was how blurry it was. There were many pictures taken before and after the final picture that were completely or slightly out of focus. However, a better camera and setup would resolve this issue quickly. If given more time, I would have loved to have tried this experiment with different liquids of different viscosities to see how they would act.

References

[1] Edge, E. (n.d.). Kinematic Viscosity Table Chart of Liquids - Engineers Edge. Retrieved from https://www.engineersedge.com/fluid_flow/kinematic-viscosity-table.htm

[2] Mass flux. (2021, September 25). Retrieved from https://en.wikipedia.org/wiki/Mass_flux

[3] Mehdi Habibi. Coiling Instability in Liquid and Solid Ropes. Fluid Dynamics [physics.flu-dyn]. Université Pierre et Marie Curie - Paris VI, 2007. English. fftel-00156591ff

[4] Zhang, Z., Lao, Y., Li, X., & Wang, Y. (n.d.). *Study of Liquid Rope Coiling* (Rep.). Shang Jiao Tong University, China: Department of Physics and Astronomy.

Appendix