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Get Wet Report

Context

This purpose of this project for the Get Wet assignment of 2018 was to demonstrate the flow phenomenon of cymatics. This video shows oil on a vibrating surface and how the vibration causes the oil to create ligaments and eventually fracture into droplets. The capturing of the "bouncing" oil looks less like standard cymatics effects due to the ligaments that are created. This has to do with the geometry of the surface, the frequency used, and the amount of oil. If a smaller amount of oil had been used—more of a film—the liquid would have formed the usual regions of maxima and minima associated with cymatics. Since more liquid was used, the maxima broke into ligaments and then droplets. This video was the second take, since the first try was focused incorrectly. I was assisted by Shane K. Mitchell, a graduate student who works in the same mechanical engineering lab as I do, the Keplinger Research Group. He helped me focus and trigger the high-speed camera.

Apparatus and Flow

To create this video, I created a dielectric elastomer actuator (DEA). This consisted of a piece of 1 mm thick VHB stretched radially and stuck onto a circular frame of acrylic that was 1 cm wide with an outer diameter of 14.5 cm. I painted circular carbon grease electrodes on either side of the stretched VHB, with carbon grease tails trailing off opposite sides so as to avoid arcing from high voltage application. Figure 1 below shows the complete actuator.

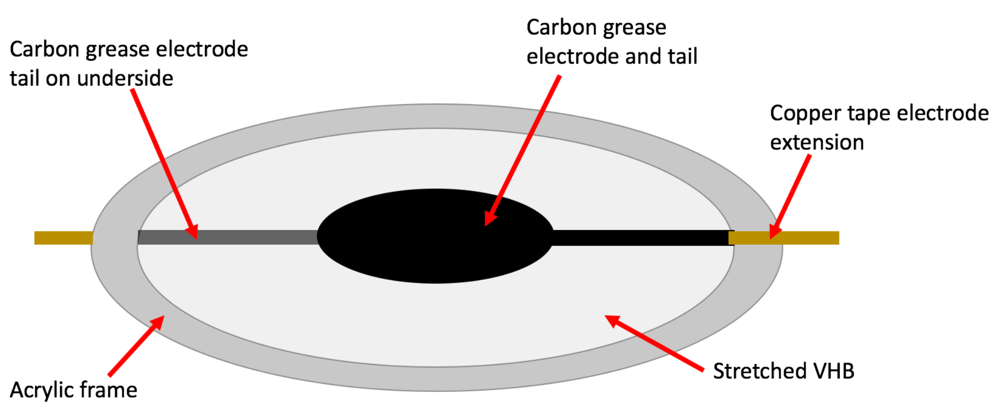

Figure 1: Completed DEA.

The DEA was supported horizontally by three clamps so as to avoid smearing the electrodes. The electrodes were attached to a high voltage amplifier and ground, and then actuated at 8 kV and 30 Hz. Before actuation began, 8 mL of Envirotemp FR3 oil were pipetted onto the actuator surface, over the circular area of the carbon grease electrodes. A high-speed camera was used to capture the fluid motion. The camera was capturing at 700 fps. The depth of field is shown in Figure 2, with a scale bar.

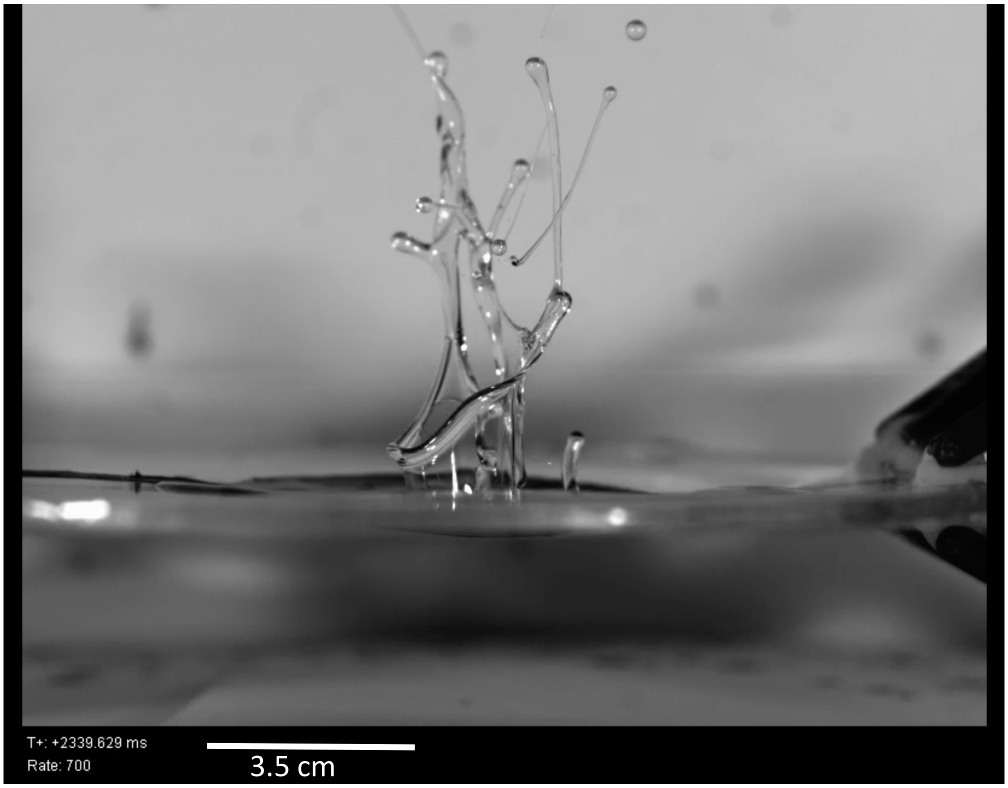

Figure 2: Still from video to show scale.

When the actuator had high voltage applied to it, the oil started vibrating, and then began bouncing and forming the ligaments and droplets. The oil has a kinematic viscosity of around 50 mm^2/sec at room temperature. The Reynolds number was probably high due to the chaotic nature of the flow, which usually means it is not laminar. However, I think a more useful value to assign to the oil would be the flow's Weber number. The Weber number[1] describes the relation between a fluid's inertia to its surface tension. In this case, the velocity of the oil was estimated to be 2.04 m/s, and the characteristic length (droplet diameter) was estimated to be about 0.5 cm. Unfortunately, values for the density and surface tension for this specific oil could not be found after extensive searching, so estimations will be made using canola oil, which is an oil that has been used for similar actuator purposes in the laboratory. The density of canola oil is 0.92 g/mL and the surface tension is about 34 mN/m at room temperature. Thus, the Weber number could be calculated as:

$$We = \frac{\rho v^2 l}{\sigma} = \frac{(920\,\frac{kg}{m^3})\left(2.04\,\frac{m}{s}\right)^2 (0.005\,m)}{0.034\,kg/s^2} = 563$$

This is a large Weber number[2] which accurately describes how the oil's inertial forces are overcoming the surface tension, forming ligaments and then droplets. Another interesting physical phenomenon that could help describe this flow is the Plateau-Rayleigh instability[3]. This describes the why and how a falling stream of fluid breaks into smaller particles with less surface area. This would describe the falling oil motion.

Visualization Technique/Photographic Technique

I used a Phantom v710 High Speed camera to capture this video. The camera was about 20 cm from the actuator. I covered the top of the camera with paper towels as to avoid oil spatter from hitting any camera surfaces or lens. While the high-speed camera can handle a rather large amount of fps (over 1 million), I only took video at 700 fps, since this was all that seemed necessary to capture the flow properly.

The video was 1280 x 800 pixels and then I cropped it down to 800 × 648 pixels during post processing. I used a tripod specific to the camera and two sets of insanely bright incandescent lights to allow the camera to see well. They were next to the tripod and aimed at the actuator. I did not change too many settings around on the camera except for the focus. I hovered my finger over where the oil would bounce to and focused the camera on my fingertip. Once the video was shot and saved, I cropped it a little on each side and slowed the play time down by fifty percent to get the satisfying effect of having the oil bounce to one's heartbeat.

What it Reveals

I really enjoy how this video reveals there is something very lifelike in the way fluids flow. Oil is usually not personified or thought of as something that could mimic anything living. Yet this video helps the oil come to life through its bouncing motion, beautiful droplets, and heartbeat like timing. The rise and fall of the ligaments and droplets is incredibly soothing and satisfying and is something you could watch all day. I really enjoy how this video exemplifies the beauty of fluid subjected to vibration. If I could change one thing, I would make the background cleaner. The small specs of oil from the first attempt are visible on the white background and they are somewhat distracting. I really enjoyed making this video since the idea was so simple for me. I make actuators all the time for work and was excited to discover how they could influence fluid motion when at high frequencies. If I were to further develop this idea, I would make a larger actuator with a larger electrode area so as to add more oil and see more fluid in motion and perhaps over a wider area.

Sources

1 Weber number. (2018, February 10). Retrieved February 16, 2018, from https://en.wikipedia.org/wiki/Weber_number

2 Splash (fluid mechanics). (n.d.). Retrieved February 16, 2018, from https://www7.dict.cc/wp_examples.php?lp_id=1&lang=en&s=Weber number

3 Plateau–Rayleigh instability. (2018, February 10). Retrieved February 16, 2018, from https://en.wikipedia.org/wiki/Plateau%E2%80%93Rayleigh_instability