IV 3: Popping Bubbles

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https://youtu.be/1KO9QJWGsrM

I. Overview of Experiment

My team's goal for this project was to get a slow motion video of a bubble popping. We had seen videos of bubble popping in slow motion in the past and wanted to recreate that. Specifically, we wanted to capture the ligaments that appear when a bubble pops.

We started out by using the Olympus i-Speed 2 camera, generic dollar store bubble solution, and a large LED grid light. The videos we captured were not only very low resolution but also only 400 fps, because we couldn't go any higher or the video would be too dark. After spending about 2 hours taking a few videos, we decided to try again another day, hoping that the use of sunlight would fix our problem of not enough light.

For round 2, we decided to use a special bubble solution, natural and direct sunlight, as well as the Sony HXR-NX80 high speed camera. With the natural sunlight, we were able to film up to 4000 fps with the Olympus camera. The bubble solution we used also made the popping of the bubbles much more dramatic. We ended up getting many amazing shots of the bubbles popping with both the Olympus and Sony cameras.

For my final video, I decided on 2 clips. The first one was taken on the Olympus camera and the second was on the Sony camera. Both videos were taken on the day we experimented outside.

II. Setup

For round 2 setup, we had both cameras (Olympus i-Speed 2 and Sony HXR-NX80) active and were taking videos on each. This setup was on the concrete The University of Colorado Boulder's Idea Forge loading dock. We had direct sunlight coming from the west over our project. The Oylmpus camera also needed to be connected to a computer monitor and be hooked into a power cord coming from inside the idea forge. To take the photo we had one person on each camera and one person blowing the bubbles.

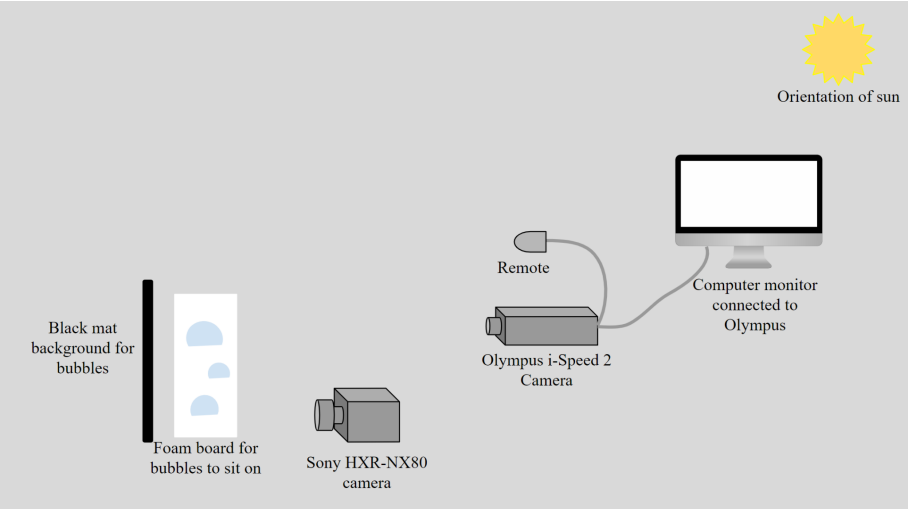


Figure 1 : *Diagram showing camera setup*

We had the bubbles fall onto a white foam board that we coated in soap solution. This provided a clean surface for the bubbles to stick to and not pop. Behind the bubbles we had a black mat that acted as a background.

For the bubble mixture, we used a combination of water, Dawn dish soap, rubbing alcohol, guar gum, and baking powder. This recipe was recommended as the best bubble blowing recipe by fluid physicists. This solution makes a stronger bubble because, "The polymer strands become entangled, something like a hairball, forming longer strands that don't want to break apart," as said by Justin Burton, a physicist at Emory University specializing in fluid dynamics[1]. The presence of the polymers also creates a webbing effect when the bubble pops which makes it look much more dramatic.

III. Fluid Mechanics

When a soap film pops (whether a flat soap film or spherical bubble), it is often caused by a hole made in the film that breaks the surface tension of the film. The rim of this hole then spreads until the entire film is gone. However, when this hole spreads, its edges don't remain smooth and instead develop indents that expand into what are called ligaments. Ligaments are like long fingers/strands of soap film.

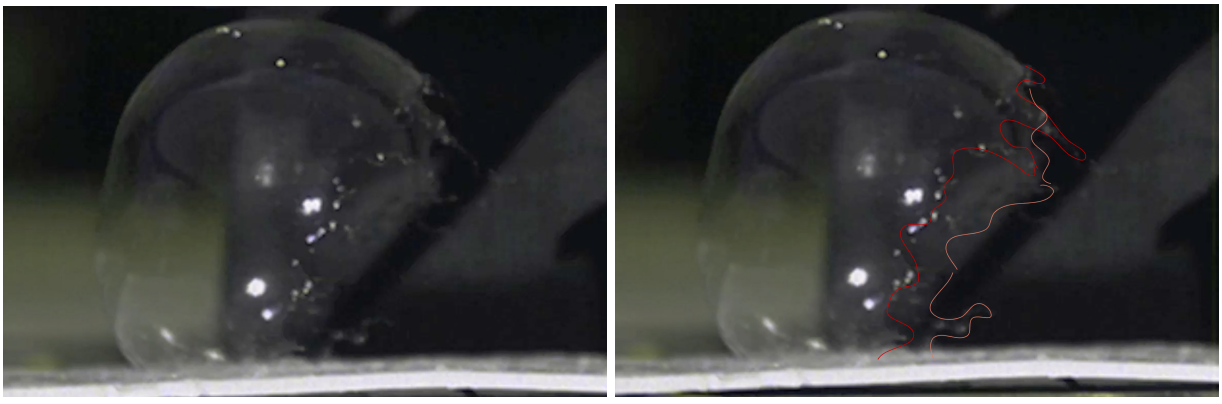


Figure 2 : *Ligaments and indents appear as the bubble pops. Still images taken from the first clip of the video taken on the Olympus i-Speed 2.*

In fig.2, indentations and ligaments are able to be seen as the bubble pops. As the bubble keeps popping, the indents expand into even more ligaments until a sliver of the original bubble remains. The remaining sliver then falls to the ground as soap residue.

In flat soap films, the ligaments that are created, will start to flap around much like a flag does in the wind. The cause of this flapping is due to shear instability and the velocity difference between the receding film and the still atmosphere. As the soap film recedes, as seen in fig.4, the flapping motion at the tip grows in amplitude[2].

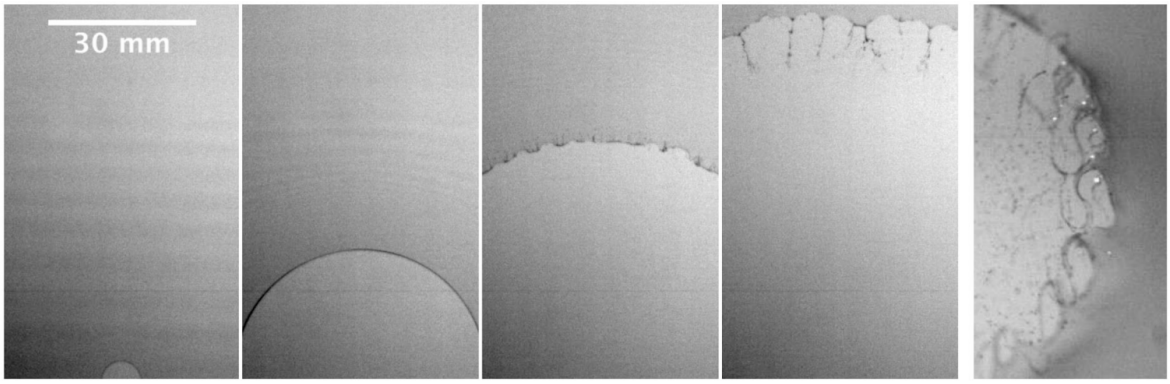


Figure 3 : *Ligaments flap around due to destabilization of the soap's edge*

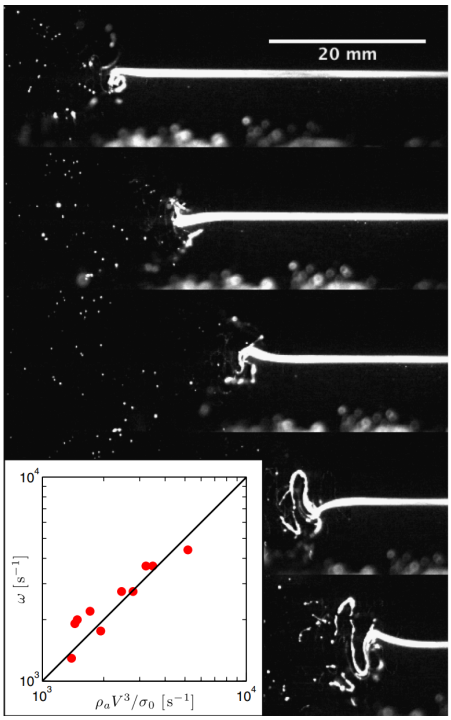


Figure 4 : *Flapping speeds up as film recedes*

IV. Photographic and Visualization Techniques

When taking the video, the camera settings were as follows:

Olympus i-Speed 2 - 4000 fps, 384x288 pixels, ~10 feet from subject, field of view ~6x5", time duration ~0.4sec, ISO: unknown.

Sony HXR-NX80 - 960 fps, 1920x1080 pixels, ~1.5 feet from subject, field of view ~10x8", time duration ~8sec, ISO: unknown.

A consequence of using the Olympus i-Speed camera was that at a higher frame rate, brightness and size would greatly decrease. At 4000 fps, the camera could only film a video that was 384x288 pixels.

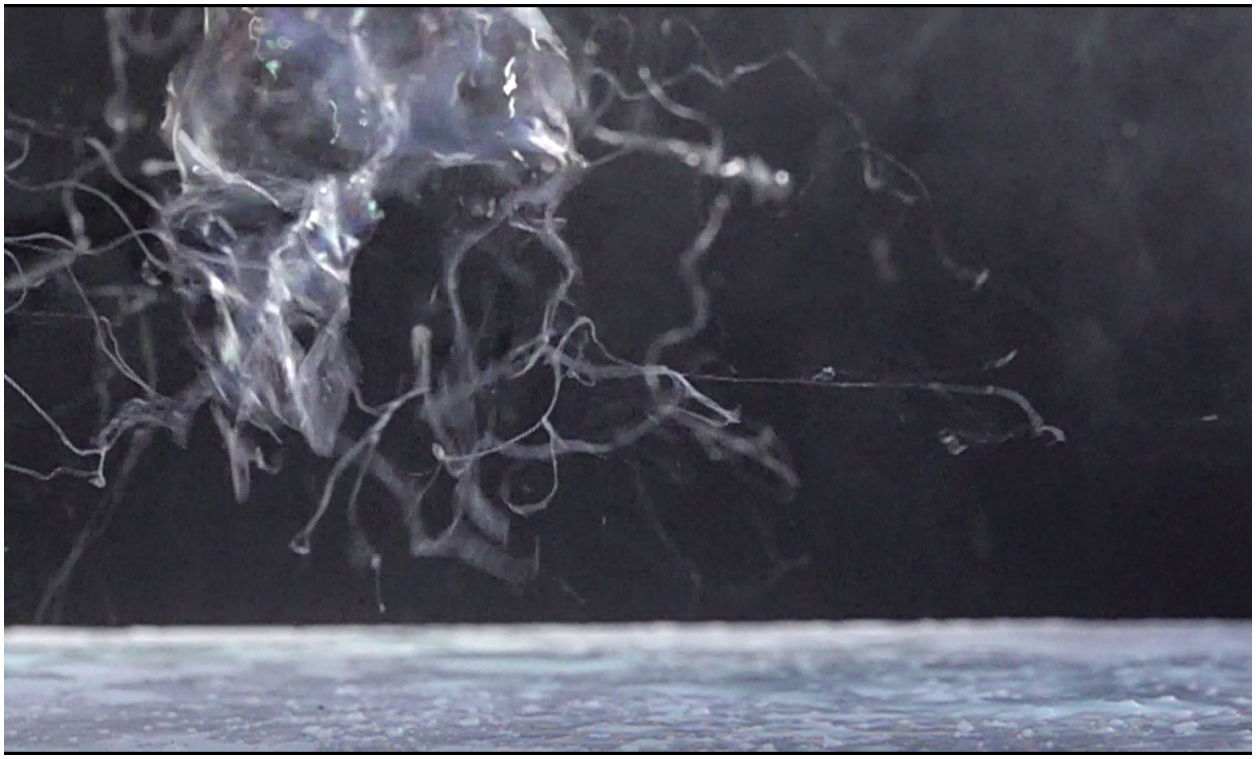
On both video cameras, the ISO wasn't able to be changed and is also not shown in the metadata of the videos, therefore the ISO of these clips is unknown.

These videos were taken at about 3pm on October 19th. There was little to no wind, a temperature of about 69°, and a humidity of about 14%[3].

I believe that both of these clips are almost completely time-resolved. They are taken at such a high frame rate, but when paused, motion blur is visible in the paused frame. These clips also have a loss of spatial resolution, especially the first (Olympus), due to the difficulty of landing a bubble within the DOF of the camera.

When editing these videos the only modifications I did were increasing the brightness by a small fraction. I also played around with playing the first clip forward and then in reverse at a different speed to add a cool popping-unpopping effect.

Original Video: Freeze frame of bubble popping, still taken from second clip, filmed on the Sony HXR-NX80.



Edited video: Freeze frame of bubble popping, still taken from second clip, filmed on the Sony HXR-NX80.

V. Image Remarks

I am really happy with how these videos turned out. Although our first attempt didn't have much success, I'm glad we decided to keep trying until we got what we wanted. Because of the special bubble recipe we were able to capture very detailed and dramatic bubble ligaments which is exactly what we were aiming for. The filming process was also a lot of fun and we played around with many other bubbles making techniques and got videos of that just for fun. While taking the videos, lots of people stopped by and asked what we were doing and it was really exciting to talk to them and show them our process and setup.

I wish that we had been able to get a higher quality high speed camera. The camera that filmed at really high speed (the Olympus) resulted in really tiny and low resolution videos, while the higher resolution camera (the Sony) took the videos at a lower frame rate.

If I were to develop this idea further, I would want to get better footage of the large bubbles that we made. The large bubbles (made by a long piece of string and 2 dowels) had very dramatic and interesting popping dynamics, but since the bubbles were so large, the background of the videos often had people or other objects that distracted too much from the bubble.

References

[1] “Ars Technica: Physicists determine the optimal soap recipe for blowing gigantic bubbles by Jennifer Ouellette.” Accessed November 07, 2022. https://arstechnica.com/science/2020/02/physicists-determine-the-optimal-soap-recipe-for-blowing-gigantic-bubbles/

[2] “Henri Lhuissier & Emmanuel Villermaux: Soap Films Burst Like Flapping Flags” Accessed November 07, 2022. https://hal.archives-ouvertes.fr/hal-00426813/document

[3] “TimeandDate: October Weather in Boulder - Graph.” Accessed November 07, 2022. https://www.timeanddate.com/weather/usa/boulder/historic?month=10&year=2022