Get Wet Report: Tubeless Siphon

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MCEN 5151 Flow Visualization

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I. Context & Purpose

Flow visualization is a very important observational technique that facilitates the research and appreciation of fluid movement patterns. In the Get Wet Assignment, a phenomenon related to fluids, tubeless siphon, will be visualized and researched. Tubeless siphon is a phenomenon in which fluids (usually liquids) are attracted to flow upward without a tube.This is in contrast to the normal siphon phenomenon where the fluid needs to be inside the pipe to be attracted by the negative pressure and flow upwards. Only some specific fluids can form a tubeless siphon. In this task, water and egg whites were used for a comparative demonstration.

II. Flow Apparatus

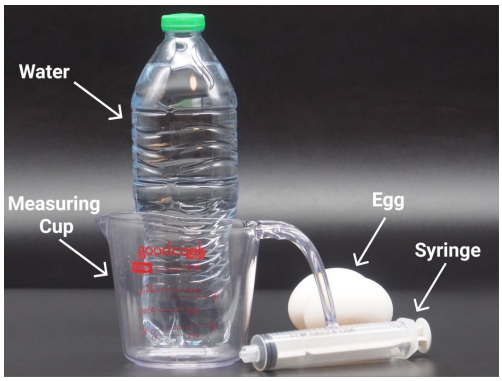

Figure 1. Items for the experiment

In this assignment, two transparent measuring cups, some water, a couple of eggs and a syringe were used. First, pour water into a measuring cup with the free surface of the water close to the one-third volume scale of the measuring cup(Figure 1). Then, insert the tip of the syringe below the free surface and pull the syringe plunger slowly to draw in water. As the syringe draws in water, move the syringe slowly, trying to let the tip above the free surface of the water. It is observed that when the tip leaves the free surface, the flow of water is immediately cut off, and the syringe can no longer draw in water, but begins to draw in air(Figure 2).

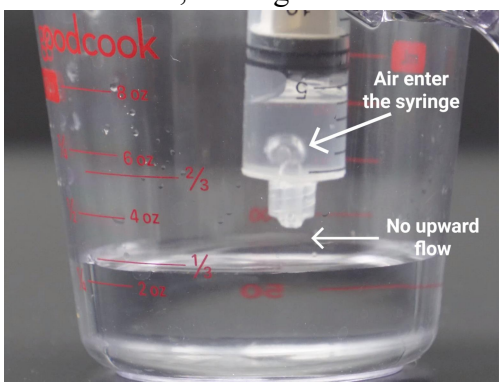

Figure 2. Water movement (control group)

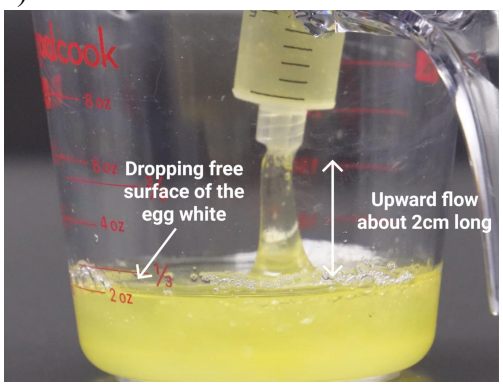

Figure 3. Egg white movement (experimental group)

Then break the egg, pour the egg white in another measuring cup and repeat the same steps as above: the free surface of the egg white is on the same scale of the measuring cup, insert the syringe and draw up the egg white. Then move the tip of the syringe upwards. Unlike water, when the tip of the syringe moved above the free surface of the egg white, the flow of the egg white was not cut off, and extended out of the free surface to enter the syringe, forming a shape similar to a mountain. This "mountain" above the free surface can reach a height of 1 to 2 centimeters. As the syringe continues to draw in and keeps the tip above the free surface of the egg white, free surface can be observed to be dropping through the scale of the measuring cup, indicating that the egg white is indeed being drawn into the syringe through this stream(Figure 3). When the syringe stops inhaling, the flow of egg white in the air is cut off and the "mountain" disappears. This is the tubeless siphon of egg whites.

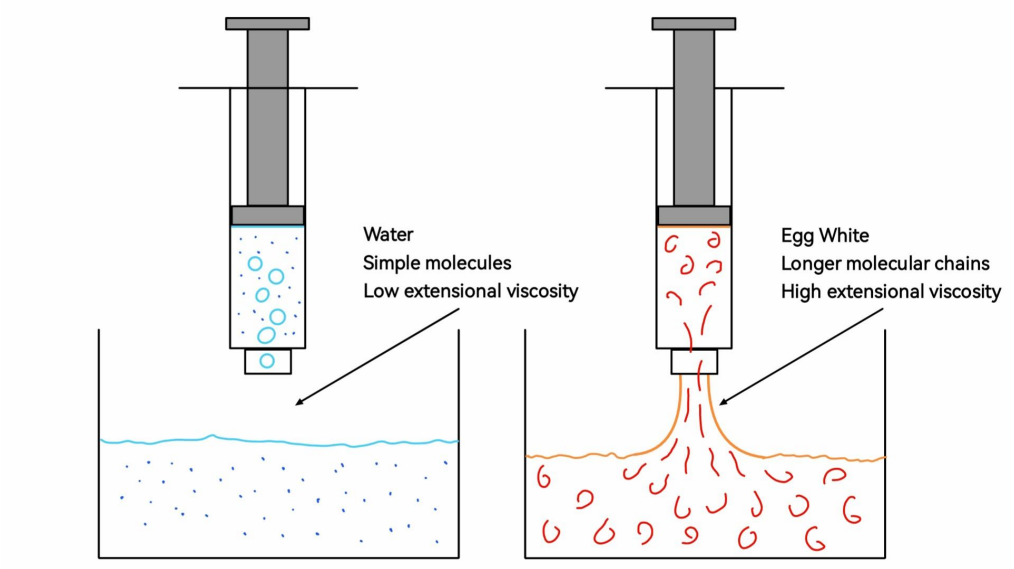

Figure 4. Egg white movement

Tubeless siphon is due to viscoelastic stresses in some non-Newtonian fluids. These fluids usually have long molecular chains, and when they are stretched, these molecular chains give the fluid a high extensional viscosity, which allows the fluid to have larger viscoelastic stresses[1](Figure 4). As the molecules at the top are attracted upward by the negative air pressure of the syringe, the viscoelastic stresses between the molecules allow the molecules above to pull on the molecules below. Finally, the viscoelastic stresses can even overcome gravity, allowing massive molecules of fluid to flow upward away from the free surface of liquids to the syringe. This is the formula of the extensional viscosity[2]:

$$\eta_e = \frac{\sigma_{zz} - \frac{1}{2}\sigma_{xx} - \frac{1}{2}\sigma_{yy}}{\dot{\varepsilon}}$$

Which η_e is the extensional viscosity, σ_{zz} is the normal stress along z directions, which assume to viscoelastic stress here, and $\dot{\varepsilon}$ is the rate of strain. With this equation, it is easy to understand that when the strain rate and the stress in the

horizontal direction are constant (assuming that the syringe draws the liquid at a relatively constant rate and that the liquid properties are uniform), the viscoelastic stress increases with increasing extensional viscosity.

Many non-Newtonian fluids are capable of forming tubeless siphon. Because their extensional viscosity increases when driven by a large external force, the viscoelastic stress will be sufficient to overcome the force of gravity. However, if the external force disappears, then the extensional viscosity will return to its normal state and gravity will immediately take over. Therefore, tubeless siphons will not persist after the syringe stops drawing in fluids.

III. Visualization Technique

In this assignment, a special fluid phenomenon will be displayed, so the visibility of the fluid is valued. To clearly illustrate the behavior of water and egg whites, transparent measuring cups were used. And the scale on the measuring cups helped to observe the change of the free surface of liquids in time: a drop in the free surface of liquids proves that the liquid was actually drawn into the syringe. In addition, the scale does help to visualize the difference between water and egg whites: when egg whites are drawn into a syringe, it is obvious by the scale that the egg whites flow upward in the air at a much higher altitude than water.

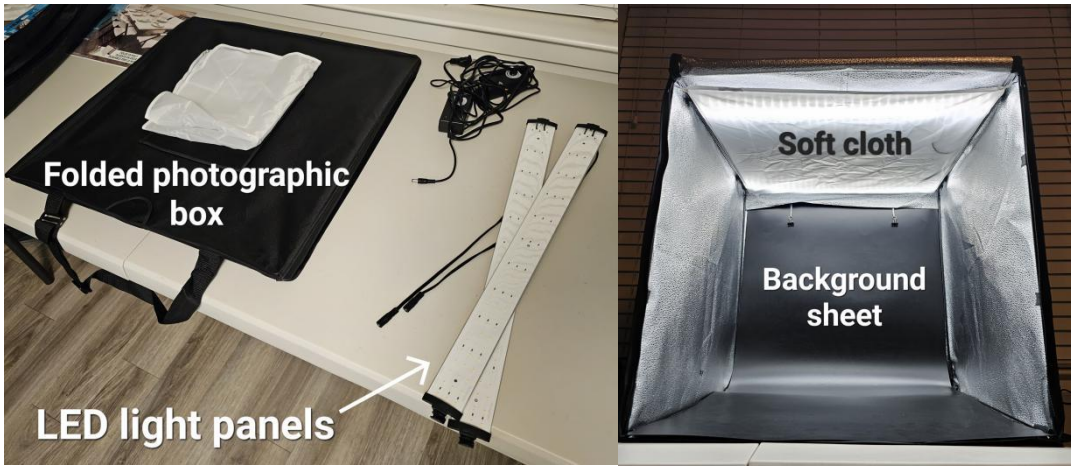

Figure 5. Photographic box

Additionally, the video was filmed in a standard photographic box(Figure 5). Two long light panels full of LED beads at the top of the box. These provide lights in all directions that are uniform, bright, and their color temperatures close to sunlight. A soft cloth below the light source. A soft cloth hanging below the light panels provides further light uniformity and prevents the various transparent tools placed at the bottom of the photographic box from clearly reflecting the annoying lamp beads. The setting up of the light source makes it easier to observe the free surface of liquids in the experiment. And a black background sheet was set up in the photographic box to

create a strong contrast of colors as possible, which helped to observe the behavior of transparent water or light yellowish egg whites.

IV. Photographic Technique

Figure 6. Camera & Lens

The edge of the camera box and the width of the background sheet is 60cm. Therefore, it is necessary to limit the size of the field of view when shooting, otherwise the walls on both sides of the box will be captured. To limit the size of the field of view, I prefer the larger focal length and chose an all-in-one lens: Tamron's 18-300mm F/3.5-6.3 lens. This lens fit a wide range of size of field of view: from wide-angle to ultra-telephoto. The camera used was Sony's ZVE-10 mirrorless digital camera with 4K 30FPS video recording capability, which is 3840 by 2160 pixels(Figure 6).

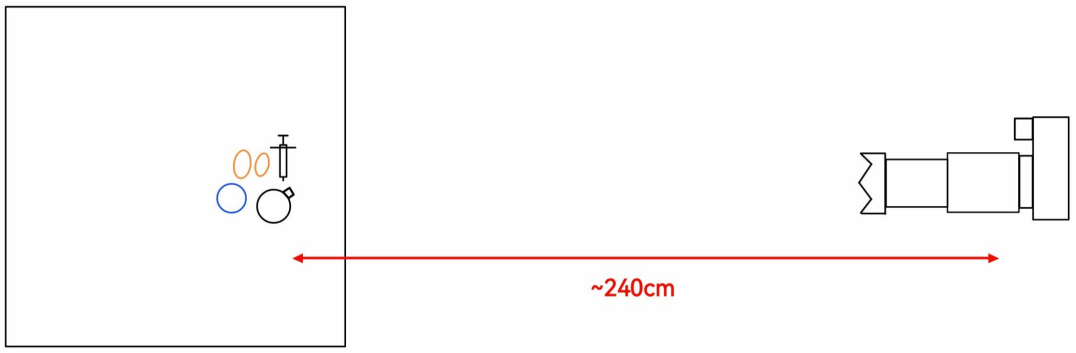

Figure 7. Recording Distance

The camera was shot at a distance of approximately 240cm from the experimental tool(Figure 7). At the beginning of the video, all items need to be shown, so a larger field of view was set. The focal length is about 100mm, and the width of the field of view width is about 40cm at this time. In transitional stages such as pouring water and breaking eggs, simply to show one of the experimental steps, the field of view thus becomes smaller. The focal length at this time is about 160 mm and the width of the field of view is about 25cm. In the most critical stage of exhibiting fluid behavior, the smallest field of view size is required to clearly show the flow of water and egg whites. At this time, the lens has reached its maximum focal length of 300mm, and the width of the field of view is only about 10cm. Because the image sensor format of the ZVE-10 is an APS-C, its equivalent focal length is 1.5 times the focal length of the lens, which is about 150mm, 240mm, and 450mm.

To get a better bokeh and make the background as less intrusive as possible. I used the camera's aperture priority mode and kept the maximum aperture during the video for each lens focal length, which was f/5.6 at 100mm focal length and f/6.3 at 300mm

focal length. To ensure that the video is as clear as possible, I recorded using 4K 30FPS and a 100MB/s bit-rate, and the video was edited without any cropping. All frame resizing was done directly through the zoom of lens. Finally, the works have a great sharpness and nicely display the details of the flow of water and egg whites.

V. Result

In this assignment, I think I chose a good topic: tubeless siphon. Initially, I just saw this phenomenon in short video media platforms and thought it was interesting. Then I chose tubeless siphon as the topic of this assignment and intended to display the phenomenon to let more people learn about this interesting phenomenon. After completing the presentation, my classmates mentioned in their feedback that they indeed hadn't seen this phenomenon before and agreed that it was interesting and that the video was of high quality. Then, I guess my intentions are fulfilled.

As I was thinking about showing a special fluid phenomenon, I chose a simple, direct and clear style, favoring the educational value. These are some of the aspects I like about my videos. However, I think I missed some aesthetic elements in this assignment. Although I asked the audience about this during my presentation and they didn't mind this, I still felt that my video needed some artistic treatment. Also, as I did not purchase the camera until after this course started, I’m a complete newcomer to the camera world. I didn't realize that shooting video doesn't record all the metadata like shooting photos, and the camera automatically adjusts shutter speed and ISO in aperture priority mode. so I failed to record the shutter speed and ISO information for all the video segments correctly. Also, the camera is cropped during video recording due to the anti-shake function, so there may be some error in the equivalent focal length and size of field of view, but the recording pixels are not lost at all. I will pay attention to these details in my next assignments.

In the future, I'll try to add some artistic tricks, like using food dyes. I believe this will make the movement of the fluid more intuitive. In addition, during my presentation, I mentioned a variety of fluids that can be used to form tubeless siphon, including polyethylene oxide, the PEO. Professor Koch mentioned that he had some storage of PEO, and I thought it would be a good idea to try tubeless siphon with PEO. Because it is far more impressive than egg whites, the liquid of PEO can flow upwards in the air up to a height of several tens of centimeters. I believe these more in depth experiments helped me to understand more about the science behind this magical phenomenon.

VI. Reference:

[1] MacMinn, C. W., & McKinley, G. H. (2004, September 26). *Tubeless siphon and Die Swell Demonstration*. Massachusetts Institute of Technology. https://web.mit.edu/nnf/research/phenomena/Demos.pdf

[2] Guyon, E., Hulin, JP. and Petit, L., *Physical Hydrodynamics*, Oxford University Press (2015), p113

The background music for the video is *Beneath the Moonlight* by Aaron Kenny. The music was published by the author on YouTube Audio Library. YouTube Audio Library is a free music library that specializes in providing creators with royalty-free music. Therefore, my using this music for the video does not create a risk of copyright violations.
Link of the music: https://www.youtube.com/watch?v=ncDCxf4meVI