Anna Gilgur
MCEN 5151
4/4/2013
Team 2 Report

Introduction

This project was the second team project of the flow visualization course that takes place at CU Boulder during the Spring Semester and is taught by Professor Jean Hertzberg. The purpose of this report is to describe how the phenomenon was visualized and captured by explaining the apparatus, physics, visualization technique and photographic technique used. For this assignment, my team (Jeremy Parsons, Jonathan Fritts, and Daniel Allen) and I decided to capture the flow of large bubbles using a store-bought bubble solution. Jonathan, Daniel, and I took the images from different angles, while Jeremy was in charge of creating the flow. The final, edited image of the flow can be seen in figure 1, below, and in figure 8 within the Photographic Technique section of the report.

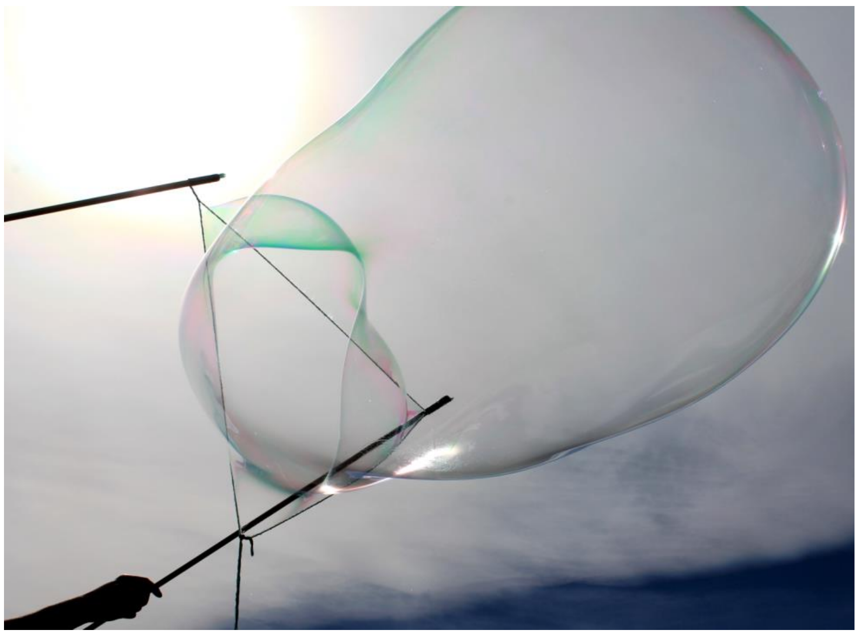
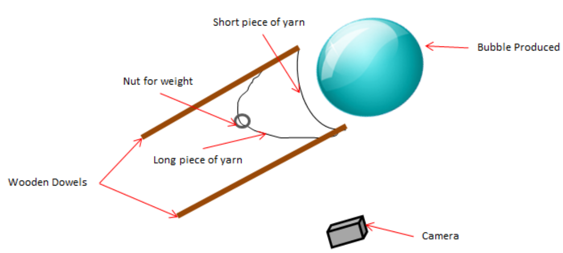


Figure 1 - Final, edited image of phenomenon

Apparatus

The flow apparatus was the same for all images captured. It consisted of two wooden dowels about 3 feet in length, two pieces of yarn (one short, one long—the long one had a nut attached to the bottom), and the bubble solution. For this image, the camera was about two feet above the ground pointed up at approximately a 60° angle. No additional lighting was used. The apparatus set-up can be seen in figure 2, below.



NOTE: NOT TO SCALE

Figure 2 - Apparatus set-up

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Physics

Bubble Formation and Surface Tension

An important property that defines the structure/size of a soap bubble is surface tension – which can be derived from one of the Laplace equations (below) [1].

$$T = \frac{PR}{2}$$ Equation 1, taken from [1]

In this equation, T is the surface tension, P is the internal pressure, and R is the radius of the bubble [1]. According to the equation, the surface tension is twice as large for a cylindrical object as for a spherical object. This is shown in figure 3, below [2].

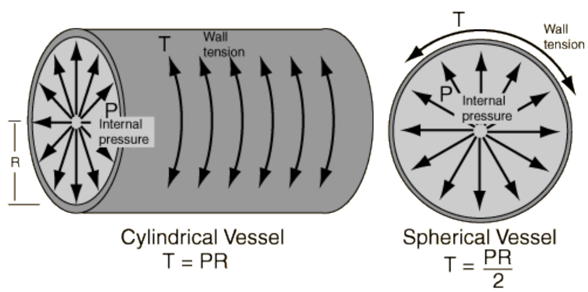

Figure 3 – Graphical representation of equation 1 (taken from [2])

Spherical bubbles form because bubbles want to minimize the surface (or wall) tension, as stated in Laplace's law, and the equation above [3]. Since for the equation above the internal pressure is difficult to determine, a different equation is used. This equation (or relationship) is dependent on the visualization that the bubble sphere is composed of two hemispheres and that the internal pressure is thwarted by the surface tension present [3]. This is seen in equation 2 and figure 4 below [3].

$$P_i - P_o = \frac{4T}{r}$$ Equation 2, taken from [3]

In this equation, P_i is the internal pressure, P_0 is the external pressure, T is surface (or wall) tension, and r is the radius.

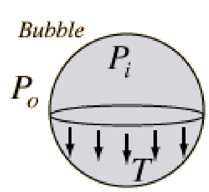

Figure 4 – Graphical representation of equation 2 (taken from [3])

Shape Formation

There are three different categories of bubbles: spherical, ellipsoidal, and spherical/ellipsoidal-cap. Spherical bubbles are so called if the forces due to inertia are less important than the tension (interfacial) and/or forces due to viscosity. Ellipsoidal bubbles refer to those that have a convex interface throughout the whole surface. Since these types of bubbles wobble or dilate periodically, their characterization is difficult. Spherical/ellipsoidal-cap bubbles are usually large bubbles that become flat at the base and do not have any symmetry (at the front and back) [4]. If the bubble is in an infinite media, a graphical relationship in terms of the Reynold's number (Re), Morton Number (M), and Eötvös number (Eo) [4]. The formulas for those three numbers and the graph are seen in equations 3, 4, 5 and figure 5 below [4].

$$Re = \frac{p d_e U}{\mu}$$ Equation 3, taken from [4]

$$M = \frac{g \mu^4 \Delta\rho}{\rho^2 \sigma^3}$$ Equation 4, taken from [4]

$$Eo = \frac{g \Delta\rho d_e^2}{\sigma}$$ Equation 5, taken from [4]

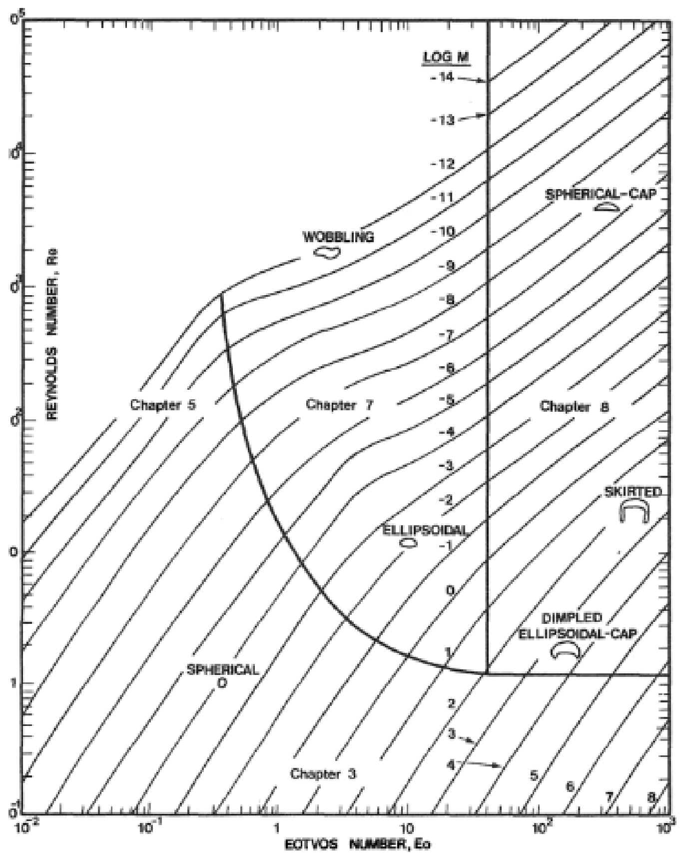

Figure 5 - Graphical relationship of equations 3, 4, and 5 (taken from [4])

Bubble Colors

The colors seen in bubbles originate from the interference colors from the soap film. The interference colors (or bubble colors) are related to the thickness of the film in each location. It should be noted that the colors also depend on the angle the bubble is viewed at [5]. Figure 6, below, is a good representation/explanation of how to get the maximum reflection and transmission of the films. The additional symbols in this figure that are not already defined are n (the index of refraction), m (the number of wavelengths), and β (angle in the film) [5].

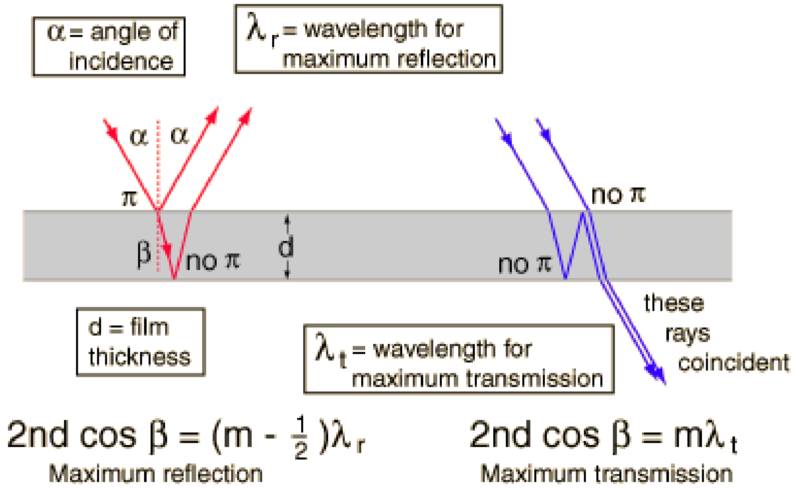

Figure 6 - Calculations for maximum reflection and maximum transmission (taken from [5])

While there is no simple way to determine the number of wavelengths (or order) of reflection seen, a diagram of spectral colors can approximate a wavelength from the color reflected from a visible soap film. In many large soap bubbles, the entire spectrum (visible spectrum) is used – although the order of interference is not evident [5].

Visualization Technique

The fluid used for this visualization was a bottle of bubbles that can be purchased at a craft store (“Miracle Bubbles”), a drop (about one teaspoon) of liquid glycerin, and some blue food coloring. The amount of bubble solution used to produce each bubble varied and as such is difficult to quantify. For this experiment, the bubble solution was picked up with the yarn/string from the apparatus described above (see figure 2 and preceding text). The wind and above physics were used to form the bubbles. No additional lighting was used because it was not needed for this image.

Photographic Technique

The camera used to capture this phenomenon was a Canon EOS Rebel T3 DSLR camera. The landscape setting on the camera was used, with the default settings selected. For this image, the flash did not fire. The size of the field of view of the original, unedited image is approximately 4 feet tall by 6 feet wide. The lens was about 6 feet away from the bubble/apparatus and the landscape mode on the camera was selected. The shutter speed, f-stop, aperture value, ISO speed, and focal length were 1/500 sec, f/18.0, f/18, 100, and 33.00mm, respectively. The original, unedited, image has pixel dimensions of 4272 pixels wide by 2848 pixels tall, while the final image has pixel dimensions of 3768 pixels wide by 2759 pixels tall. Refer to figure 7 for the original image and figure 8 (or figure 1) for the final image.

Adobe Photoshop CS2 was used to edit the original image. The tools used were: crop, spot healing (on a few blemishes), and brightness/contrast. For brightness/contrast the brightness bar was set to 0, and the contrast bar was set to 15. These modifications transformed the original image (figure 7) into the final image seen in figure 8.

Figure 7 - Original, unedited image

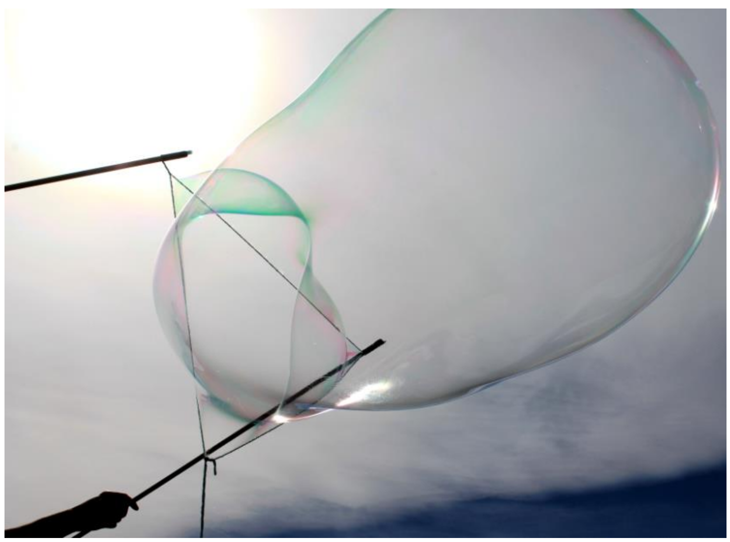

Figure 8 - Final image

Conclusion

This image does a good job at showing how the giant bubbles, and bubbles in general are formed. I like the depth of field, and colors that are present. I feel that the hand and wooden dowels add an interesting perspective to this image and give it a good reference scale. I think that the fluid physics are very well shown and defined in this image. I dislike that the top of the bubble is not present; however I don't think that it detracts from the image. My intent with taking and presenting this image was to show off large bubbles and that intent was fully realized. To further develop this idea, a video of the bubbles forming and breaking could have been shown. While there is always room for improvement, I am pleased with how this phenomenon was realized and shown.

References

[1] "Untitled Document." *Untitled Document*. N.p., n.d. Web. 20 Mar. 2013. <http://ffden-2.phys.uaf.edu/311_fall2004.web.dir/Ryan_Rankin/Whatarebubbles.htm>.

[2] Nave, R. "Wall Tension." *Pressure*. N.p., n.d. Web. 20 Mar. 2013. <http://hyperphysics.phy-astr.gsu.edu/hbase/ptens.html>.

[3] Nave, R. "Surface Tension and Bubbles." *Surface Tension*. N.p., n.d. Web. 20 Mar. 2013. <http://hyperphysics.phy-astr.gsu.edu/hbase/surten2.html>.

[4] Clift, R., John R. Grace, and Martin E. Weber. *Bubbles, Drops, and Particles*. New York: Academic, 1978. 26-27. Print.

[5] Nave, R. "Soap Film Interference." *Thin Film Reflection and Interference*. N.p., n.d. Web. 20 Mar. 2013. <http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/soapfilm.html>.