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Team #3 Movie - MCEN 5151
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The final project of the Flow Visualization class was to develop an image working with a team. The goal of this assignment was to provide more complicated image or movie by collaborating with team members on ideas and setup of flows. Our team decided to reproduce an experiment on YouTube.com[1] that had dry ice in water and used the CO2 vapor to blow up a soap bubble. Team members that assisted with this visualization are Felix Levy, Aaron Lieberman, and Gabriel Paez.

Figure 1: YouTube video[1]

The setup for an experiment simply required a bowl, tap water, dry ice, a rag, and soap. The bowl was filled with roughly an inch of tap water, and a chunk of dry ice was placed in the bowl. Then the bowl rim is coated with a dish soap solution (water and heavy with dish soap), and a rag soaked with the dish soap solution was dragged across the bowl to create a film seal. A dark garage with a black drop cloth was used as the setting. Christmas lights and a halogen shop light provided the lighting effect that was desired.

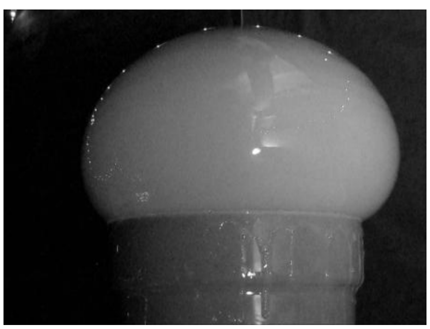

Figure 2: Dry ice gas making bubble

A few items are occurring with the production of the bubble. They are sublimation of the CO2, surface tension of the soap bubble, and buoyancy of the CO2 vapor. Dry ice sublimates at −78.5 °C (−109.3 °F) at atmospheric pressure.[2] So when a piece of dry ice is placed in 60 °F tap water, it flashes quickly into a gas. Then the soap film is placed across the container to trap the CO2 gas and inflate a bubble. With the sublimation occurring so fast, the volume increases rapidly and builds up pressure on the bubble. At a certain pressure the bubble will burst.

The surface tension of the bubble keeps the CO2 vapor separated from the atmosphere until the change in pressure is too high, causing the bubble to pop. The surface tension of soap is 1/3 of water's, or 0.025 N/m[2]. This allows soap to maintain its bubbles, unlike water which collapses. The equation for changes in pressure with regard to surface tension is:

$$P_i - P_O = \frac{4\gamma}{r}$$

P_i is the inside pressure, P_O is the outside pressure, γ is the surface tension, and r is the radius of the bubble.[4] The inside pressure that caused the bubble to burst can be calculated with this equation. Finding the gauge pressure ($P_O = 0$) with a bubble of a radius 5 inches (0.127 m),

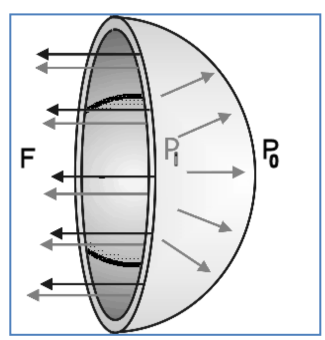

Figure 3: Forces on bubble[3]

the inside pressure is calculated as:

$$P_i - 0 = \frac{4(0.025\frac{N}{m})}{0.127m} = 0.787\frac{N}{m^2}$$

This means that the inside pressure had to be greater than 0.787 Pascal, or 10^{-4} psig to pop the bubble. That is an incredibly small change in pressure.

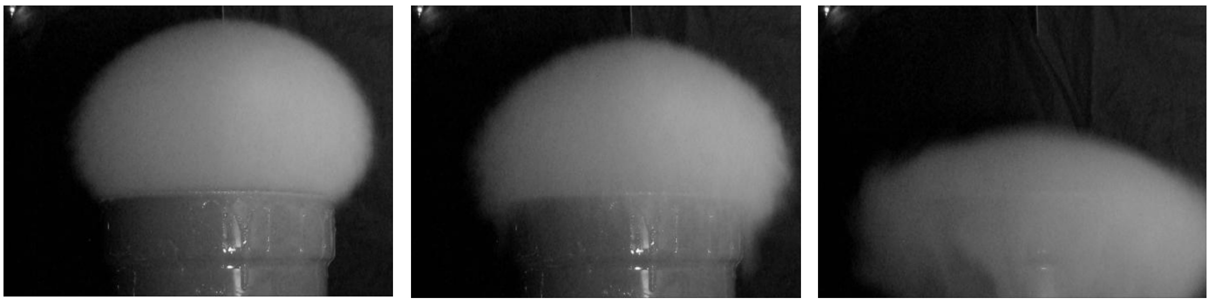

Figure 4: Time lapse photos of bubble bursting

The other force that was working during this experiment is buoyancy. Right after the bubble popped, the CO_2 gas immediately dropped towards the table since CO_2 gas is heavier than air. Air's density is 1.205 kg/m^3 and CO_2 is 1.842 kg/m^3 at 20°C. This proves that CO_2 gas should collapse towards the table since it is denser than air and has more mass per volume. Figures 4 show the time lapse of CO_2 gas. The vapor still has the shape of the bubble when the surface tension is exceeded and the bubble pops. Then the gas, being heavier than air, collapses towards the ground.

The size of the field of view is approximately two feet square. The camera used was a Canon PowerShot SD 870 IS and was used in the auto mode. The original video resolution was 640 pixels wide and 480 pixels high. The video was modified using Windows Live Movie Maker program. Black and white was used instead of the color since the effect shown is more pronounced, and it also eliminated noise by using a yellow filter. The speed of the video was increased by 16x to show the growth of the bubble since it took a while to form, but the effect is cool. Then the speed was slowed to 1/8x to show the physics of the burst. The Movie Maker program increased the resolution to 1440 pixels wide and 1080 pixels high.

The video reveals the birth and death of a bubble due to the expansion of dry ice gas, and the images from the video are amazing, showing well the physics going on with all of this. I did fulfill my intent by capturing a good bubble formation and pop. I am very satisfied with this video, probably my best of the class. There are some improvements that can be made for a better quality video and image such as better lighting or centering the subject.

References

[1] Video on Youtube.com showing the dry ice and bubble:
http://www.youtube.com/watch?v=76CNkxizQuc

[2] Dry ice on Wikipedia: http://en.wikipedia.org/wiki/Dry_ice.

[3] http://labman.phys.utk.edu/phys221/modules/m9/surface_tension.htm.

[4] Surface tension information: http://scipp.ucsc.edu/~haber/ph5B/bubble.pdf.