Coca-Cola Eruption

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Purpose

This is the fourth assignment given to us by the Flow Visualization course offered by the University of Colorado Boulder Mechanical Engineering Department. This assignment was also the second team assignment in which we were able to work in small groups and collaborate on potential visualization ideas or if desired we could work individually. For this assignment I worked in a group of five and we collectively came up with the idea of the common Mentos and Diet Coke reaction. Although this is a very common experiment done by kids all over the world, it is rare to come across a well taken photo of the flow. I have done this experiment myself many times as a kid, but for once I will be able to gain knowledge of the scientific and physical side of this fascinating reaction.

Approach

In order to see the best flow possible, we used the most common combination of a two-liter Diet Coke bottle and mint Mentos. The setup of the experiment can be seen below in figure (1).

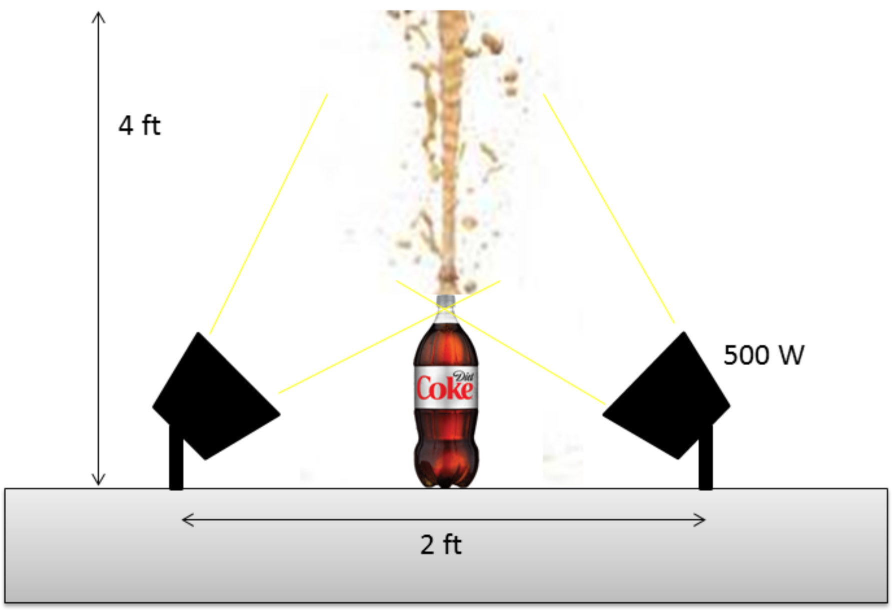

Figure 1: Setup

Mythbusters found that the reason that mint Mentos work the best is that they are uncoated meaning that there are thousands of microscopic holes all across the surface of the Mentos. So what feels like a smooth surface is actually rough and has a very large surface area due to all these microscopic craters [1]. Mentos are also fairly dense so they sink rapidly and generate bubbles towards the bottom creating a rapid fountain generation, while if the Mentos were crushed the fountain is much smaller since the pieces don't sink as fast [3]. A whole Mentos also creates a larger nucleation process creating a larger amount of bubbles than a small piece alone. Along with surface area, surface tension is a prime factor in bubble growth rate. It was found that the surface tension is lower in water containing a sweetener as compared to sugary soda, which explains why Diet coke creates a better jet than regular Coke [3]. The coatings in the Mentos contains an important surfactant as well, gum Arabic which reduces the surface tension even more meaning less work is needed to expand already formed bubbles, as this is occurring, nucleation is also proceeding forming new bubbles in the new dissolved gaps [4]. It is the combination of both of these processes that allows for such a large jet to be formed. Bubble growth in porous media is not entirely understood, researchers are developing numerical simulations by observing Hele-Shaw cells and 2D etched micro models and hypothesizing about the behavior in different media [5]. Although this report is quite old, so I am sure there has been significant advancement in understanding principle behaviors of nucleation on various medium.

Two people achieved fame when the stumbled upon this phenomenon, Stephan Voltz, a lawyer, and Fritz Grobe, a professional juggler. They introduced their creation on a comedy show in 2005. The crowd went wild and the two became target for both the Mentos and Diet Coke Corporations, becoming walking advertisements for the companies. With thousands of mints sent to them and Coke sponsoring them they set of 101 bottles of coke using 500 Mentos creating a video masterpiece. They both achieved instant notoriety as they were video legends doing hundreds of demonstrations, even performing on the David Letterman Show [2].

The physics are clearly well documented, and the reaction is well understood, but what about the actual fluid movement of this flow? From this photo I took, the Reynolds number can be easily calculated by first estimated the speed of the falling foam created by the jet. Since it is falling about 4 inches in the 1/28 sec shutter speed, the velocity is about 3 m/s. The Reynolds's number can be calculated using equation (1) below.

$$Re = \frac{inertial\ forces}{viscous\ forces} = \frac{VL}{\nu} = \frac{\left(2.8\ \frac{m}{s}\right)(.1\ m)}{(13.82x10^{-6}\frac{m^2}{s})} \approx 20{,}000 \qquad (1)$$

With such a high Reynolds number you can see that the inertial forces are much higher than viscous forces since the fluid is moving through the air. This high value also indicates the falling foam from the jet is falling in a turbulent manner. However, the jet exiting the bottle is very laminar so the Reynolds number is in magnitude of 10^3, equation (2) calculates the exit velocity.

$$Re = \frac{VD}{\nu} \rightarrow V = \frac{\nu Re}{D} = \frac{(13.82x10^{-6}\frac{m^2}{s})(2000)}{.025\ m} \approx\ 1.2\ m/s \qquad (2)$$

Visualization Technique

Our visualization technique is a well-known reaction created by combing uncoated mint Mentos with a two liter bottle of Diet Coke. Other combinations can be made such as substituting Diet Coke with regular, but this particular interaction creates the largest eruption. We placed a single two liter of soda outside on a cement ledge, and quickly dropped in a given amount of Mentos. For the first run, we only dropped in one Mentos, the second run we dropped in two Mentos, and finally the third run we dropped in four Mentos. In order to get a god shot the person dropping in the Mentos had to move very quickly since the reaction occurs immediately. For the lighting we used two 500 watts work lams pointed 45 degrees upward situated to the left and right of the two liter bottle. We conducted the image at night so these two work lamps were the only source of light.

Photographic Technique

For this single image I used my Nikon Coolpix L105 12 MP digital camera. The bottle was about ten feet away from the lens and the field of view is about four feet high by two feet wide. The focal length was 19 mm with an F-stop of 4.7 and a slow exposure time of 1/28 sec and an ISO-3200. The original image is 2048 pixels high by 1536 pixels wide while the final image was 1922 pixels high by 1076 pixels wide. The original image can be seen below in figure (3).

Figure 2: Original Image

In order to achieve the final image I used Photoshop CS5 and played with the curve line until I felt the eruption was well defined from the background. The trees and brush behind the bottle was very distracting so I made the background as black as I could and then used the clone stamp tool to eliminate any remaining background so that only the bottle and the eruption would be clearly visible. I then adjusted the contrast and brightness until everything popped out and all details were as visible as possible.

Conclusion

This image clearly reveals the powerful reaction between two simply everyday items, Diet Coke and mint Mentos. When I was taking the images they seemed very cool in the display of my camera, but when I saw them blown up on my computer screen I wasn't as impressed. I wish I would have borrowed someone else's camera to get a better time resolved photo. Even though my image could have been a little bit better, I am still very pleased with experiment and I enjoy the opportunity to understand something that seems so simple but there are a lot of physics and chemistry involved. If I were to go further with this experiment I would have tried other combinations using regular Coke and fruit Mentos and seen how they reacted. Overall, I am pleased with my image and I am glad that I got to do something so cool and actually say it is for school.

[1] Cheskin, Steve, prod. "Mentos and Soda." Perf. Hyneman Jamie, and Savage Adam. *Mythbusters*. Discovery Channel: 9 Aug 2006. Television. <http://www.youtube.com/watch?v=LjbJELjLgZg>.

[2] King, Rachel. "The Diet Coke and Mentos Explosion." Business Week Online. Pg. 25. Feb. 12, 2007.

[3] http://www.newscientist.com/article/dn14114-science-of-mentosdiet-coke-explosionsexplained.html

[4] http://antoine.frostburg.edu/chem/senese/101/consumer/faq/mentos.shtml

[5] Li, Xuehai. Yortsos, Yanis. Visualization and Simulation of Bubble Growth in Pore Networks. University of Southern California. March 1994.