Team Photo 1

Dry Ice Submersed in Oobleck

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MCEN 4151: Flow Visualization

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Purpose

The purpose of this assignment was to satisfy requirements for the first team photo assignment and experiment with flow visualization techniques within a group for the first time. The requirements of this assignment were to make an aesthetically pleasing picture of fluids that demonstrate a phenomena being observed. For the purpose of this lab, the project chosen was to submerse dry ice into colored oobleck. The intent was to observe this phenomenon as well as capture a multi-colored, interesting image of a fluid flow.

Flow Apparatus

The experiment was performed in a rectangular plastic storage container. The container was chosen to give a flat surface for the oobleck to be visualized from as to not distort the phenomena and plastic was chosen instead of glass to avoid distracting reflections or glares in the image. The size of this container is approximately 11 inches by 5 inches and 4 inches deep filled with about 3 inches of oobleck. Oobleck is made by combining cornstarch with water. Many batches of oobleck were made but the recipe that seemed to work best was about 2 boxes to a quart of water. If the oobleck was too thin, the phenomena could not be properly observed and if it was too thick, it would freeze around the dry ice also making it impossible to observe the phenomena. Dry ice was also purchased from a local grocery store for this experiment and after the oobleck was made and poured into the plastic container, small pieces of dry ice were placed in the oobleck with tongs and would slowly submerse through the oobleck to the bottom where the phenomena could then begin happening. The dry ice pieces were about 2 to 3 inches in diameter, any bigger and the pieces would not stay at the bottom of the oobleck (which is desired to observe the phenomena) or it would start to freeze the oobleck. The food coloring used in this image can be purchased at any local grocery store and came in small dropper containers making it easy to use. The food coloring was not combined in the oobleck but was instead dropped over the oobleck after bubbles started forming from the submersion of the dry ice. It is important that the ink be dropped in small quantities to visualize the flow of the oobleck and for that reason only one drop of dye was used at a time. The diameter of the droplets is roughly 4 millimeters wide which proved to be effective for this experiment. The droplets were released about 3 to 4 cm above the oobleck to avoid excessive splashing.

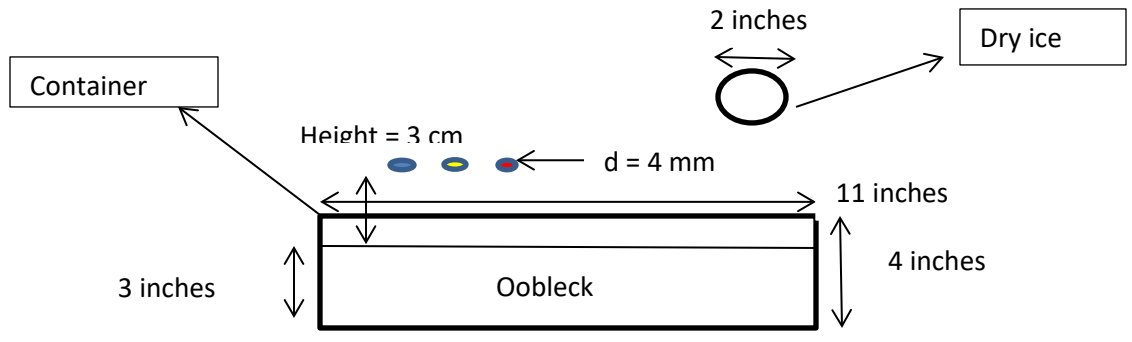

Figure 1: Flow Appartus Setup

Flow Dynamics

This image was generated using a combination of gas dynamics and non-Newtonian fluids. Oobleck is a non-Newtonian fluid meaning it has properties of both a solid and a liquid. The viscosity (the ability of the fluid to resist gradual deformation by shear or tensile stress) of a non-Newtonian fluid is dependent on shear rate[1]. The relationship between shear stress and shear rate is non-linear for oobleck making it act like a fluid but feel more like a solid. Dry ice was submersed in the oobleck and because the fluid is non-Newtonian, it took a while before the dry ice would make it towards the bottom of the container. Upon the submersion, the sublimation of the dry ice causes gas packets to form within the fluid. As the expansion occurs, the oobleck begins forming bubbles and the non-Newtonian properties allow these bubbles to grow quiet large. Upon reaching a certain critical growth size, the bubble is ruptured and a jet, consisting of a combination of CO_2 and condensed water vapor erupts from the oobleck in a geyser- like fashion. Because the oobleck is non-Newtonian, the bubble did not just disappear when it would rupture like a soap bubble would. Rather, the bubble would rupture with a slit were the gas would escape and then slowly decay. When the bubbles were formed, food coloring was dropped onto the bubbles to visualize them better. Because the dry ice would cause rotation of the bubble, the bubbles would have a tie-dye effect where the food coloring was carried across the bubble. Also, sometimes the food coloring was dropped on the bubble right before rupture. When the bubble ruptured, it sent food coloring droplets flying off to the side. The velocity of these droplets can be approximated by looking at where they landed with respect to the bubble they left. These blue drops can be seen in the image and their velocity can be approximated by the equation below:

$$V = \frac{distance}{time}$$

, where the distance is approximated as roughly 10 cm and the time it took this drop to leave the bubble and land is roughly 0.1 m/2. This approximation estimates the velocity of the drops of food coloring at about 1 m/s. This is a really rough approximation. The approximation would be better used performing the analysis with projectile motion equations as this approximates the behavior of the system better. However, the angles from which the droplets are launched are unknown.

Visualization Technique

Blue and green ink were used to achieve a more interesting, multi-colored picture with an artistic appeal; however, this experiment could be performed using just one color of dye or even no dye at all. The dye was used to not only make the image more dramatic but it helps to

[1] *Wikipedia*. Wikimedia Foundation, n.d. Web. 06 Nov. 2015.

visualize the flow better. If only the white oobleck is photographed, the image can look washed-out without perfect lighting and this makes it much harder to visualize the phenomena present. We had a team of four people to make the oobleck, drop the dry ice in, add food coloring where the bubbles appeared and take photos. However, since the phenomena would stick around for a very long amount of time (even up to 30 minutes), there is plenty of time for photographing and the entire experiment could be set up and photographed by one individual.

In this setup, a black background was used. This was achieved by placing a black window curtain behind the container. The curtain was draped over a table outside and along the ground. The oobleck container was then placed on the curtain with the curtain also behind it for the background. The lighting used was just natural sunlight outdoors. This experiment was performed on a sunny day, mid-day, to achieve enough lighting. Once the apparatus was all set up and the experiment performed, the camera was placed about 6 to 7 inches from the bubble and manual focus was used to zoom in and focus on the middle bubbles.

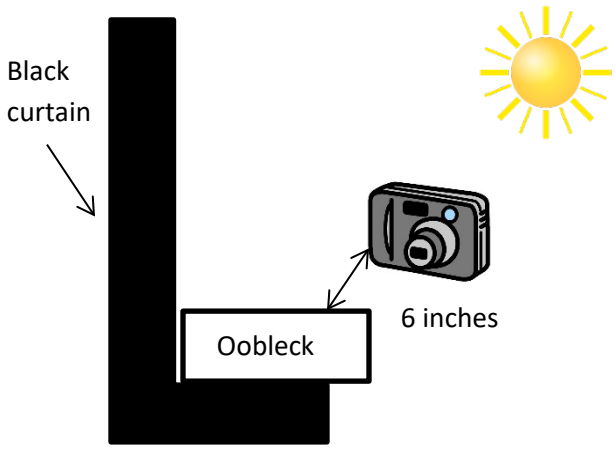

Figure 2: Camera Setup

Photographic technique

This photograph was shot using a Sony α 5000 E-mount camera with an attached 16 – 50 mm power zoom lens. This point and shoot mirrorless camera has manual focus capabilities with an ISO up to 16,000.[2] The image size shot is 5456 x 3632 pixels and the final image after processing is 4680 x 2536 pixels. The focal length used for this shot was 50 mm which is equal to 75 mm for a 35mm equivalent range. The image was captured using a shutter speed of 1/160s and the ISO was only 100 to reduce blurring and noise. These settings in addition to the setup described earlier and the exemption of the flash led to the photo in figure 3 below.

[2] "Sony α5000 E-mount Camera with APS-C Sensor." *Sony*. N.p., n.d. Web. 16 Oct. 2015.

Use of an open – source photo editing program Gimp was then used to create the final image. The image was cropped to focus only on the phenomena (the bubbles and geysers) and to get rid of the container and backdrop. The image was then saturated a little but most importantly the contrast was increased to make the bubble stand out more against the bright, white oobleck. The post – processing after image is also shown below in figure 3:

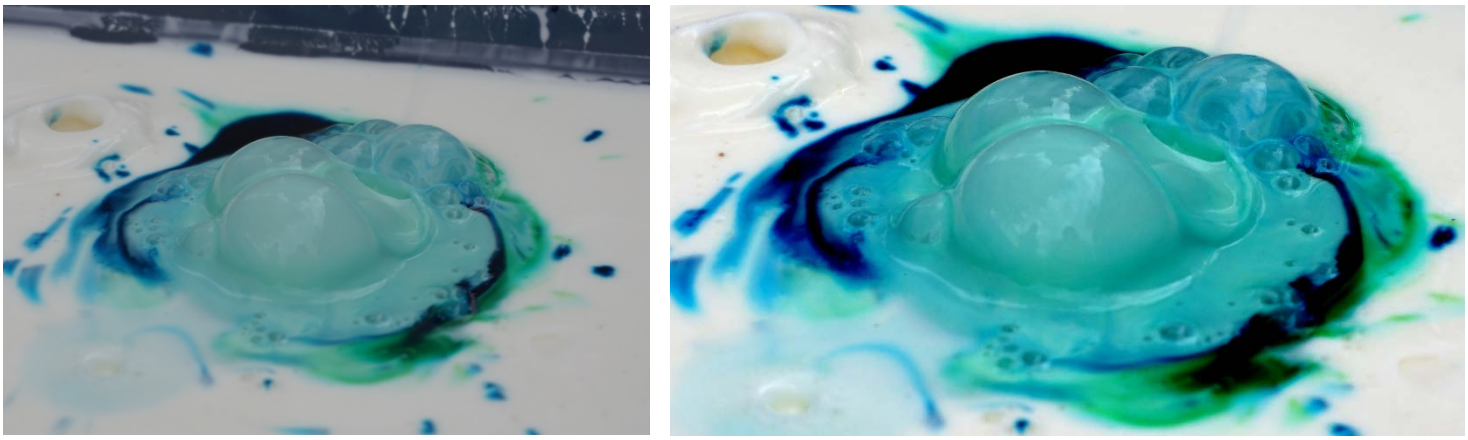

Figure 3: Raw image (left) and processed image (right)

Conclusion

The project was successful in experimenting and understanding flow visualization techniques within a team. Being able to work on a team allowed us to create more original and complicated experiments as well as collaborate on understanding the physics behind the fluid flow. There were various attempts made on this project which resulted in understanding the experiment and discovering what methods worked or did not worked such as consistency of the oobleck or size of the dry ice pieces. This experiment is another proof of the importance of having a good apparatus and flow setup to create a proper image of the phenomena.

The image revealed important fluid concepts in an artistic and colorful way. I really enjoyed that I was able to capture multiple bubbles in this image and even capture one of them at the time it was rupturing. I was also able to capture some of the tie-dye effect made in the bubbles by the rotation of the food coloring and two different geysers of water vapor and CO_2. I also think my focus is nice on the focal point of my image. If I were to perform this experiment again, I might try to take the image from a more horizontal angle to try to capture the black backdrop so that the vapor and gas from the geysers can be seen in the image. However, I was able to capture a lot of interesting physics of fluid flow in this image and I feel like because of this, I fulfilled my intent with this photograph. If I were to develop this idea further, I would try to adjust the dry ice and oobleck more to achieve even bigger, more dramatic bubbles.