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Team Project 1 Report

This image was taken for the "Team Project 1" project, and was done in collaboration with Matthew Feddersen, Bradley Samuels, Daniel Anson, and Michael Vallejo. The intent of the project was to capture a non-Newtonian fluid, known as oobleck (this name was derived from the popular Dr. Seuss book, "Bartholomew and the Oobleck"[1]), in various shear situations (since they are known for their shear thickening properties); shear thickening fluids are also known as dilatants [2]. The image was taken on Friday, March 4, 2011 in the Durning Lab of the CU Boulder Engineering Center during one of the preliminary attempts to set up the fluid for video capture. This was actually recorded on the day before the majority of the other team members obtained their images or videos. The final video product actually consisted of one experimental setup pertaining to the oobleck per person merged together to be a sequential showcase.

The apparatus used in this experiment consisted of cornstarch, water, food coloring dye, and a bucket. The setup was relatively simple, the corn starch and water was mixed inside the bucket (figure 1), the blue food dye was then added but not mixed. The bucket was rotated with the open mouth facing the camera in order to get video footage and pictures of the mixing process. Following this, the bucket was held at a 30 degree angle below the x axis facing the camera. This picture was taken approximately 10 seconds after the bucket was held stationary.

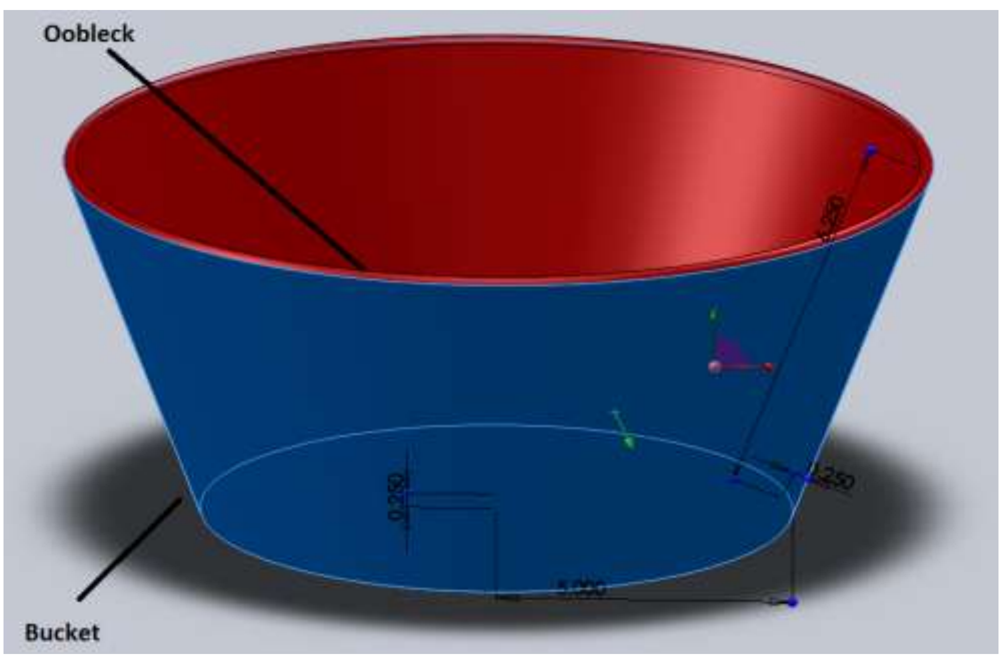

Figure 1. Apparatus involving a bucket containing oobleck.

First, the most important thing for any fluid flow is to calculate the Reynolds number in order to determine whether the flow is turbulent or not. Balmforth et al.[3] performs a derivation and finds the Reynolds number calculation of oobleck to be the following [1]:

$$Re = \frac{U^2}{g*H*\sin(\theta)} \quad (1)$$

Where:

$$U = surface\ flow\ speed$$

$$g = force\ due\ to\ gravity$$

$$H = height\ of\ flow$$

$$\theta = angle\ of\ incline\ of\ plane$$

The surface flow speed was relatively low, approximately 10 cm/s (0.1 m/s). The force due to gravity is assumed to be a constant 9.81 m/s^2. The height of the flow varies due to the nature of the fluid, so let us assume, for simplicity that the average height of flow is 1 cm (0.01 m). The angle of incline of the bucket was 30^o, and the bucket itself had a natural 15^o outward incline to it, so we will take the angle to be 45^o. When punching through the numbers, we get 0.012, which should indicate laminar flow. Surprisingly though, according to the previously mentioned Balmforth et al.[3] study, there is an odd phenomenon that occurs at low Reynolds numbers in dilatants called roll waves. This is something that can be seen in the image (on the surface of the bulk of the flow). This is likely due to the nature of the fluid where the center of the flow is compressed due to the shear caused by the flow on the ends of the profile. The fluid near the top is experiencing much lower shear, so it has more fluid properties, but as it travels farther, it experiences more shear and is overtaken by the fluid behind it as it becomes more solid like.

As previously mentioned, this image was taken in the Durning Lab of the CU Boulder Engineering Center on Saturday, February 19, 2011. The conditions for the image were not ideal since a backdrop was not available at the time, so I had to go in with Photoshop and edit the background to be a solid color. The lighting was created by a high intensity lamp from the flow visualization storage area. The oobleck itself was a mixture of corn starch purchased from King Sooper's, tap water, and fluorescent food coloring. Blue dye was used for this mixture primarily for aesthetic reasons as well as to fit the mood theme I try to create in my images.

The field of view was approximately 5.5 in and the distance from the object to lens was approximately 3 ft. The lens focal length was 30 mm with an ISO speed of ISO-200. The exposure time was 1/60 seconds and the max aperture was 3. A Panasonic DMC-FZ100 (rated for 14.1 Megapixels) digital camera was used to capture the image. The pixel width x height is 4320 x 2432. Photoshop was used to crop the original image (original dimensions were 2916 x 2432). Additionally, the magnet lasso tool was used to isolate the shape of the flow and create a layer of a solid color for the background.

I wanted to create a feeling of motion, but at the same time, a feeling of silence; almost as if this were happening in a world where only this phenomenon exists and nothing else. The main thing I like about the image is how much there is a definite contrast between the surface texture of the oobleck experiencing high shear and the oobleck undergoing very little shear. The viewer can tell that the shiny surface areas are undergoing very little shear due to the fact that it maintains the appearance of a liquid. The dull areas that kind of resemble a paste like substance are undergoing a lot of shear since oobleck is known for its shear thickening properties. It would be nice to have an actual backdrop for this image, but it was unfortunately not possible with the setup we had going. To further develop this idea, it would be fun to see what happens when suspending the corn starch in other fluids than water (such as cooking oil). Additionally, maybe a flammable liquid and set the whole thing on fire?

References:

[1]Fensch, Thomas. *The Man Who Was Dr. Seuss: the Life and Work of Theodor Geisel*. Woodlands, Tx.: New Century, 2000. 95.

[2] Cengel, Yunus A., and John M. Cimbala. "12, Compressible Flow." *Fluid Mechanics: Fundamentals and Applications*. Boston: McGraw-Hill Higher Education, 2010. 611.

[3]Balmforth, N., J. Bush, and R. Craster. "Roll Waves on Flowing Cornstarch Suspensions." *Physics Letters A* 338.6 (2005): 479-84.