# Flow Visualization: Team Photo 3

MCEN 4151: Flow Visualization

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## Purpose

The goal of this image was to capture the phenomenon of a non-Newtonian fluid. A non-Newtonian fluid is a fluid that does not behave under Newton's model of fluid flow. Instead, the viscosity of a non-Newtonian fluid is dependent on shear rate.[1] This means that the viscosity is not a set value because it will change based on the flow characteristics. In simpler form, a non-Newtonian fluid will act as a solid in response to an abrupt force and as a liquid when being poured. We chose to use a fluid defined as Oobleck: cornstarch suspended in water. If you fill a tub with Oobleck, you are able to punch or step on it and it will absorb the impact as a solid, but if you try to pour it out, it will act as a liquid. Very impressive and slime-like visualizations can be seen using Oobleck, and it is extremely amusing to play with. The image was made possible with the help of two team members: Jennifer Milliken and Zachary Brunson.

## Flow Apparatus

The physical flow apparatus consisted of two spatulas and a 20 inch aluminum bowl. The key element to this visualization is to use the correct cornstarch to water ratio to create the Oobleck fluid. We used 6 pounds of cornstarch and 8 cups of water which were mixed in the bowl. To create a more interesting image we dyed the Oobleck using a bottle of neon green and electric blue food dye. This allowed us to create the effective green slime-like appearance of the Oobleck. A white slab of acrylic was placed behind the bowl to white out the background. The apparatus was lit from the right side at about a 45 degree angle. The only light used was an industrial construction light. The spatulas were used to allow the Oobleck to drip and settle as they fell back into the bowl. Both spatulas had holes in them which allowed the fluid to ooze through. The flow apparatus is shown below from the perspective of the photographer.

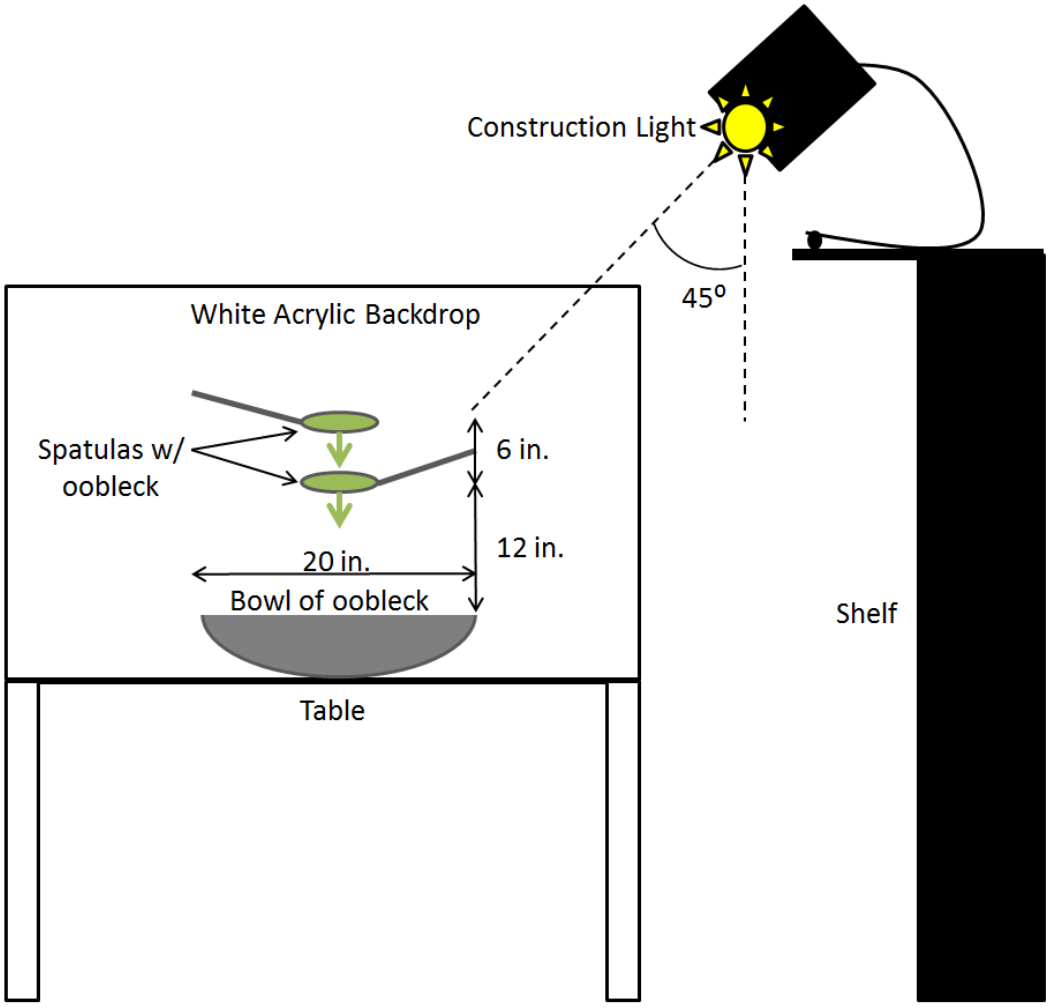


Figure 1: Flow Apparatus from Front / Camera Perspective

## Flow Dynamics

Oobleck can be characterized to have a time-independent viscosity and to display shear thickening (dilatant). This means that the viscosity will increase with increased stress.[2] The figure below shows a shear stress vs. strain rate curve of the dilatant or shear thickening (Oobleck) compared to Newtonian fluids and pseudo plastics or shear thinning.

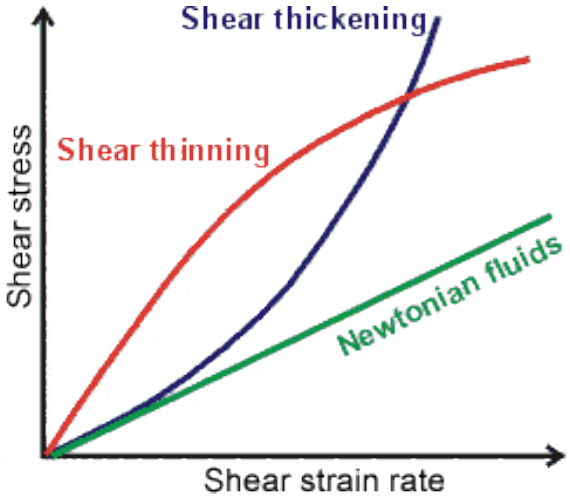


**Figure 2: Shear Stress vs Strain Rate for non-Newtonian and Newtonian Fluids[2]**

The Reynolds number for the Oobleck falling through the air can be used to better understand the physics of the presented flow phenomenon. Reynolds number is calculated:[3]

$$Re = \frac{\rho * V * d}{\mu} = \frac{U * D}{v}$$

where U is the velocity of a finger of Oobleck, D is the diameter of the finger, and $v$ is the viscosity of the Oobleck at its given flowing state. The velocity was determined to be about 0.5 inch per second (0.01 m/s) and the diameter was determined to be 1 cm. Since Oobleck has a varying viscosity, I assumed that the viscosity as it falls through the air was two times the viscosity of honey. I assumed it was about 0.0002 m^2/s (twice that of honey).[4]

$$Re = \frac{U * D}{v} = \frac{0.01\frac{m}{s} * 0.01m}{0.0002\frac{m^2}{s}} = 0.5$$

This very small Reynolds number is to be expected because the Oobleck traveled extremely slowly and linearly as it descended which defines a laminar flow.

## Visualization Technique

To achieve the best visualization, several techniques were used. We used a single light source and no flash. The position of the light source was shown above. We also chose to use two spatulas to show how the Oobleck behaves like a liquid and cascades down from the top spatula, then behaves like a solid and settles on the bottom spatula, and finally behaves like a fluid and seeps through the bottom spatula. The dye was also very effective in creating a slime feel. We eliminated shadows by taking the photograph perpendicular to the

light. Also, it was very important to keep the two spatulas still, so the Oobleck would not shake and fracture as it fingered downwards.

## Photographic Technique

The camera used was a point and shoot: Canon PowerShot SX230 HS (12.1 megapixels, 14x optical zoom, f3.1-5.9, 28-392mm (35mm equiv)).[5] The original photograph is 12 megapixels (4000 X 3000). The ISO was set at 200 (low sensitivity) to remove noise and ensure a clean image. The shutter speed was set to 1/30 of a second which allowed enough light to enter but captured the motion of shot without blur. Aperture was f/3.1 which allowed an effective volume of light to enter the lens.[6]

Very little post processing was done using Photoshop. I cropped the image to zoom in on just the flow aspects. I also changed the contrast slightly to enhance the detail and colors. This brought out the intense green and made the shadows more distinguishable. I played with the level of yellow to white out the background but preferred it at its current state. A before and after of the image are shown below.

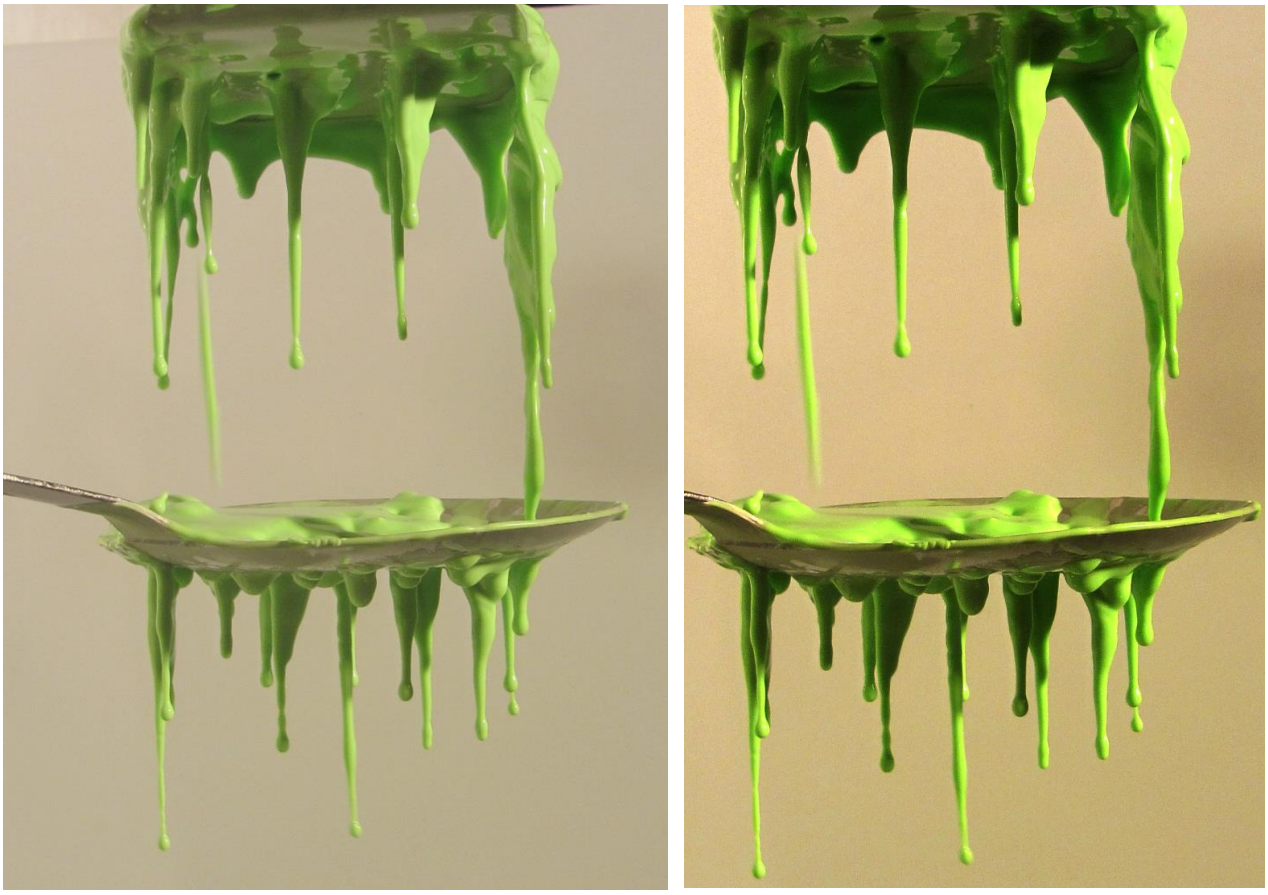

**Figure 3: Before (left) and After (right) of Image**

## Conclusion

Oobleck is a very easy way to explain the phenomenon of a non-Newtonian fluid. It has been used to entertain and teach students of all ages. Using it to create flow visualizations can be very fun and interesting. I feel that this image fulfilled its purpose and was very successful.

## References

[1] "Latest Homepage." Latest Homepage. N.p., n.d. Web. 30 Apr. 2013. <http://www.non-newtonianphysics.com/>.

[2] http://www.lsbu.ac.uk/water/hyrhe.html

[3] "Reynolds Number ." Engineering ToolBox. N.p., n.d. Web. 14 Mar. 2013. <http://www.engineeringtoolbox.com/reynolds-number-d_237.html>.

[4] "Viscosity Tables." V&P Scientific, Inc.. N.p., n.d. Web. 30 Apr. 2013. <http://www.vp-scientific.com/Viscosity_Tables.htm>

[5] " Canon PowerShot SX230 HS: Digital Photography Review." *Digital Photography Review*. N.p., n.d. Web. 12 Feb. 2013. <http://www.dpreview.com/products/canon/compacts/canon_sx230hs/specification>.

[6] "Exposure | Understanding Exposure - ISO, Aperture and Shutter Speed Explained." ExposureGuide - Photography Tips, Techniques and News. N.p., n.d. Web. 14 Mar. 2013. <http://www.exposureguide.com/exposure.htm>.