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Group Project Photo #2

“Creature from the Black Lagoon”

This photograph was taken for the second group for the flow visualization course at the University of Colorado at Boulder. The picture is an interesting demonstration of the behaviors of non-Newtonian fluids being excited by sound waves emanating from a stereo subwoofer. Different mixtures of Oobleck and different frequencies were tested to achieve the desired response from the fluid to create unique structures within the fluid during excitation.

Oobleck is a type of non-Newtonian fluid, which consists of a simple mixture of corn starch and water. It is named Oobleck after the 1949 Dr. Seuss book "Bartholomew and the Oobleck" in which the young boy Bartholomew must recue a kingdom from a sticky precipitation called Oobleck [1]. There are several non-Newtonian substances, and they are defined by the fact that they have flow properties which differ in any way from classical Newtonian fluids. The flow property that most commonly differs from Newtonian fluids is viscosity [2]. In a Newtonian fluid there is a linear relationship between shear stress and shear rate, whereas in a non-Newtonian fluid this relationship is non-linear, and can even be time dependent [2]. The Oobleck is therefore defined as a Dilatant fluid, and the relationship between shear rate and shear stress can be seen compared to a Newtonian fluid in figure 1.

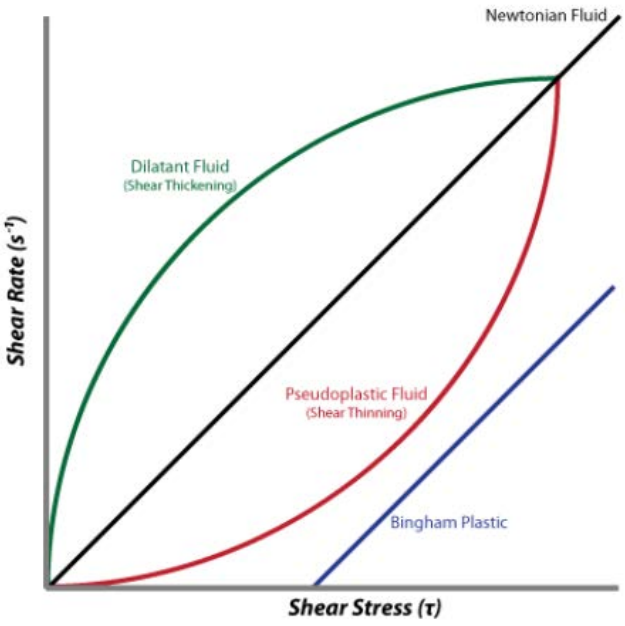

Figure 1: Shear stress vs. Shear Rate

A dilatant fluid is a non-Newtonian fluid in which the viscosity increases with the applied shear stress, and this is where the fluid parts ways with Newtonian law [3]. The suspension of the corn starch particles creates the counterintuitive behavior of the Oobleck, which is also commonly called a shear thickening fluid [3]. Therefore, when the Oobleck is excited by the

vibrations of the sound waves it begins to increase its viscosity, and thicken. As the vibrations thicken the Oobleck rapidly, it can begin to stack upon itself in the thickening process and build the interesting amorphous formations seen in this image. The Oobleck is also called a visco-elastic fluid, a sub class of the non-Newtonian fluids due to its properties of flowing under small forces, but sustaining brittle fracture under higher forces applied to it [4]. Researchers at the University of Texas at Austin in the Center for Non Linear Dynamics who were researching this fluid were able to distinguish a phase diagram for the fluid that had four distinct regions that change as a function of acceleration and frequency [4]. The four regions were labeled as unstable, meta-stable, stable, and delocalized [4]. It is this delocalized region where the Oobleck will experience a collection of material onto itself which resulted in “fingers” rising as high as two centimeters above the surrounding material before collapsing in their experiments [4].

In the submitted photograph a mixture of cornstarch and water was made using two parts cornstarch to one part water. The mixture was poured onto a flat baking sheet. The baking sheet was placed onto a large subwoofer speaker and then sine wave tones were played at high volume through the speaker. The speaker is a Rockford Fosgate ten inch Punch 4 ohm subwoofer. It was powered by a Sony BD-E7, 80 Watt home stereo system. Different tone frequencies were experimented with to determine that the ideal frequency to be used was 70 Hz to achieve optimal excitation of the fluid. The excitation structures were typically about one to two centimeters in height. The field of view was approximately five to ten centimeters. The experimental setup is illustrated in the diagram in figure 2. The cornstarch was obtained from the local grocery store. Since the mixture is nothing but cornstarch and water, it is safe and non-toxic. The lighting used was ambient room lighting as well as two halogen flood lamps placed on either side of the speaker assembly.

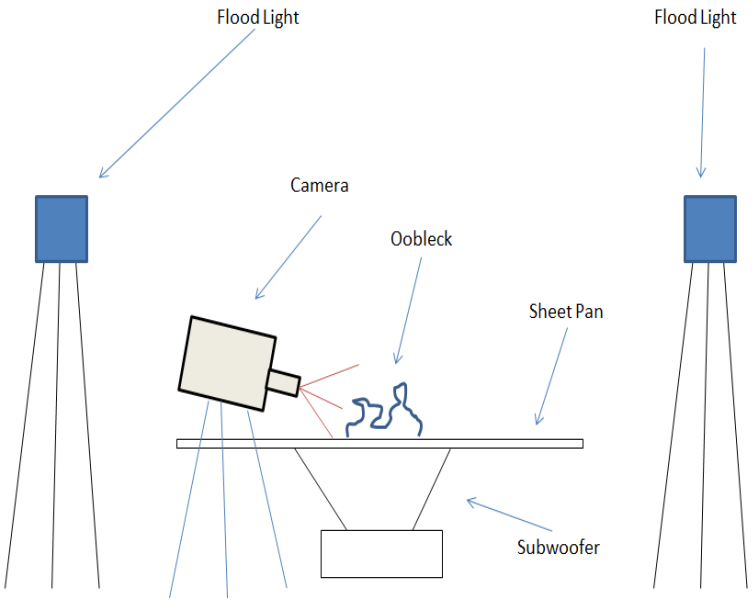

Figure 2: Experimental Apparatus

Due to the size scale of the structures forming in the Oobleck the field of view was quite small, approximately five to ten centimeters. As a result the camera was quite close to the fluid. The photo was taken with the camera about 20 to 30 centimeters from the fluid. Because the fluid structures would not last for a long time, a relatively fast shutter speed was needed to capture the structures and avoid motion blur. The picture was taken with a Sony DSLR model A-230 digital camera. The exposure time was set to 1/250 seconds. The F stop was 5.6, and the ISO was set to 100. The focal length was 55mm and there was a 2x magnifying filter screwed onto the end of the lens. There was no flash used. The horizontal and vertical resolutions were 350 dpi. The pictures final dimensions were 2369 pixels in widths by 2160 pixels in height. The flood lamps that provided the bulk of the lighting were placed about two to three feet from the surface of the baking sheet pan and they were both 500 Watt lamps. There was some post production editing done to increase the dramatic feel of the image. It was processed in Photoshop by first cropping the image to focus on the amorphous structures. The temperature was shifted to the red side of the scale. The contrast was increased significantly and the brightness was increased slightly.

This image in interesting in that it not only reveals the odd behavior of non-Newtonian fluids in a whimsical way, the amorphous entities captured resemble a potential scene from a science fiction movie where the scary monster is rising from the depths of a murky swamp. The color enhancements give it a very dramatic feel. The physics are clearly represented and the depth of field in the image gives it a focused foreground, but also shows other structures in the background. It would be entertaining and interesting to experiment further with the Oobleck

to capture images of more curious structures formed by the fluid. It was an easy, safe, interesting, and fun experiment to execute and can be achieved by a wide range of people who wished to repeat the image. Overall, it was a successful attempt at capturing the fluid flow phenomenon.

References:

[1] http://en.wikipedia.org/wiki/Bartholomew_and_the_Oobleck

[2] http://en.wikipedia.org/wiki/Non-Newtonian_fluid

[3] http://en.wikipedia.org/wiki/Dilatant

[4] http://arstechnica.com/science/news/2005/11/1771.ars