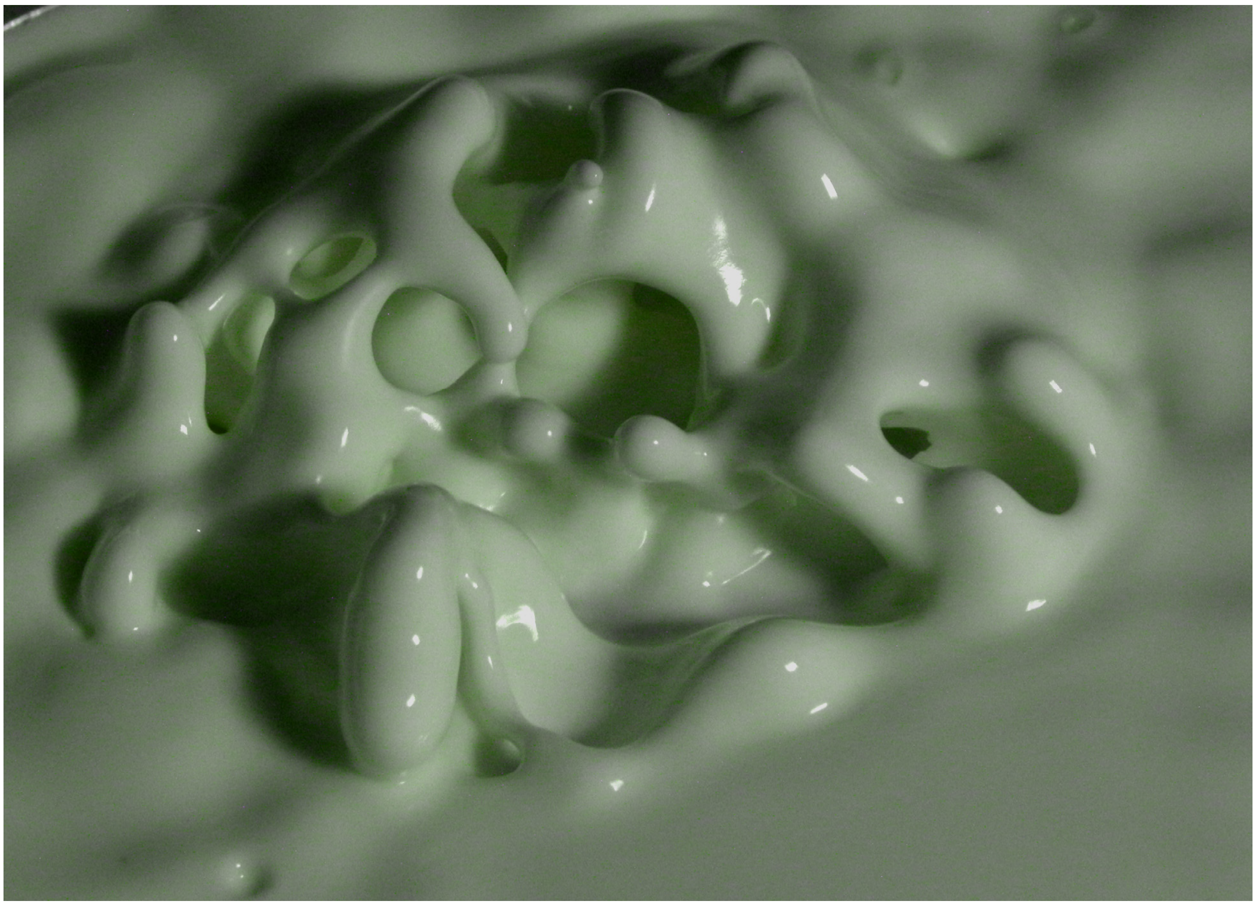
Non-Newtonian Fluid Reacting to Long Stroke Shaker



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I. Introduction

This image was taken as part of the second group project in the Flow Visualization course at the University of Colorado at Boulder. The intent of this image was to capture the unique characteristics of non-Newtonian fluids and how they react to sustaining forces. In this case, a dilatant non-Newtonian fluid was subjected to oscillatory shear forces exerted by a long-stroke shaker at a constant amplitude and frequency.

II. Background

A non-Newtonian fluid is one which does not obey the classical laws of physics as described by Isaac Newton. In particular, a non-Newtonian fluid has a nonlinear relationship between shear stress and strain rate, whereas a traditional Newtonian fluid has a linear relationship between shear stress and strain rate [1]. This results in non-Newtonian fluids lacking a single constant value of viscosity.

The non-Newtonian fluid used in this experiment was a mixture of corn starch and water (often called "oobleck"), which is classified as a dilatant material [2]. A dilatant is a non-Newtonian fluid in which the viscosity of the fluid increases with increasing amounts of applied shear stress [1]. The difference between the shear stress vs. shear rate curve for a traditional Newtonian fluid and a dilatant non-Newtonian fluid is shown on Figure 1, below, where the shear rate is the rate at which a shear force is applied [2].

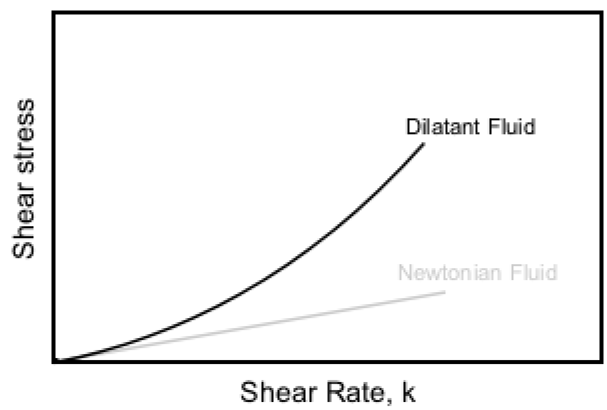

Figure 1. Shear stress vs. shear rate (k) for dilatant fluid and Newtonian fluid.

The dilatant effect occurs when closely packed particles (in this case, corn starch) are combined with enough liquid to fill the gaps between them [1]. At low velocities, the liquid acts as a lubricant and the dilatants flows easily. At higher velocities, the liquid is unable to fill the gaps created between particles, and friction greatly increases, causing an increase in viscosity. The increase in viscosity reaches a point at which the fluid begins to behave like a solid [3].

III. Experimental Setup

This experiment was conducted in the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado at Boulder. An eight inch pie tin with a hole machined in it was rigidly attached to the long-stroke shaker in the ITLL with a nut and bolt. The fluid comprised of two parts water, one part corn starch and was poured into the pie tin until it was about half an inch thick (about 12 ounces of fluid). The shaker was continually adjusted using the waveform generator and amplifier attached to the shaker shown in Figure 2 until the natural frequency of the mass was found. The natural frequency was evident when the non-Newtonian fluid "danced" after it was stimulated with any object and was found to be 45 Hz in this case. The shaker was powered by a 2 Volt peak-to-peak amplitude sine wave. Upon finding the natural frequency of the fluid, it was left shaking and continued to be stimulated by the oscillatory forces of the shaker. At this point, the engineers were able to observe the "dancing" oobleck which is shown in the image. The experimental setup is shown below in Figure 2.

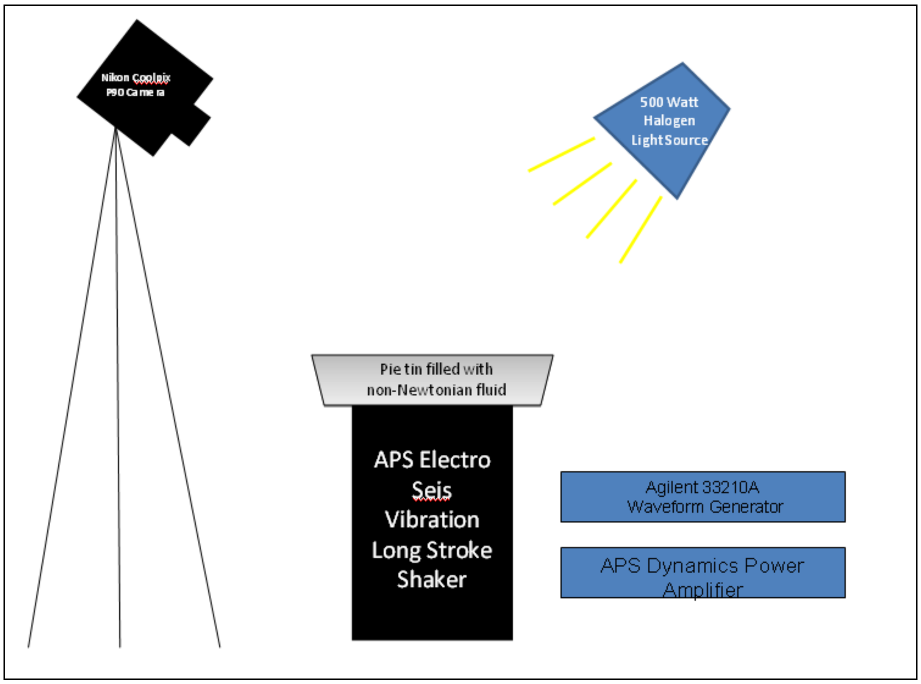

Figure 2. Schematic diagram of experimental setup

IV. Photographic Technique

To adequately capture this image, the camera was situated on a tripod foot and a half above and six inches behind the fluid. The camera used was a digital Nikon Coolpix P90. The engineers chose to use an F-stop value of f/4.5 with a maximum aperture value of f/2.8. The ISO was set at 200 to achieve a low light sensitivity which results in better resolution and less motion blur for quickly moving fluids. To counter the low light sensitivity resulting from a low ISO number, a 500 Watt halogen light was shone directly on the fluid one foot above and six inches behind the fluid. The focal length of the camera was 37.7 mm. The field of view of the original image was about six inches wide and high. The original image was 4000 pixels wide by 3000 pixels high at a resolution of 300 dpi.

To enhance the field of view of the photo, the image was cropped to include only the reacting non-Newtonian fluid. The cropped image is 3075 pixels wide by 2208 pixels high at a resolution of 300 dpi. The crop successfully highlighted the most interesting part of the photo. In the cropped version of the image, there is a nearly perfect circle formed by the fluid which is about two-thirds the way up the photo and one-third the way from the left of the photo. It is very pleasing to the eye to have such an interesting part of the photo at such a location and obeys the compositional rule of thirds [4]. The final image also has increased contrast and saturation, which allows the viewer to perceive the depth of the fluid and the details of the shear thickened fluid.

V. Conclusion

This image successfully reveals the interesting nature of a non-Newtonian fluid reacting to sustaining oscillatory shear forces. The engineer particularly likes the depth present in the image and the shadows the fluid creates on itself. She likes the way the image can be seen simply as fluid or can be construed to portray other things such as creatures and caves. There is a distinct beauty present in the abstract nature of this image which allows the viewer to create his or her own reality of what it could be.

VI. References

[1] Thomas B. Drew and John W. Hoopes, Jr., *Advances in Chemical Engineering*, Volume 12. 1956. pp 86-87.

[2] Non-Newtonian Fluid – Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Non-Newtonian_fluid. Accessed on 29 March 2010.

[3] Dilatant – Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Dilatant. Accessed on 29 March 2010.

[4] Rule of Thirds – Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Rule_of_Thirds. Accessed on 02 April 2010.