Impact of Model Car in Non-Newtonian Fluid, Video

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Video Link: **https://www.flowvis.org/2022/09/05/oobleck-car-drop-ryan-wells/**

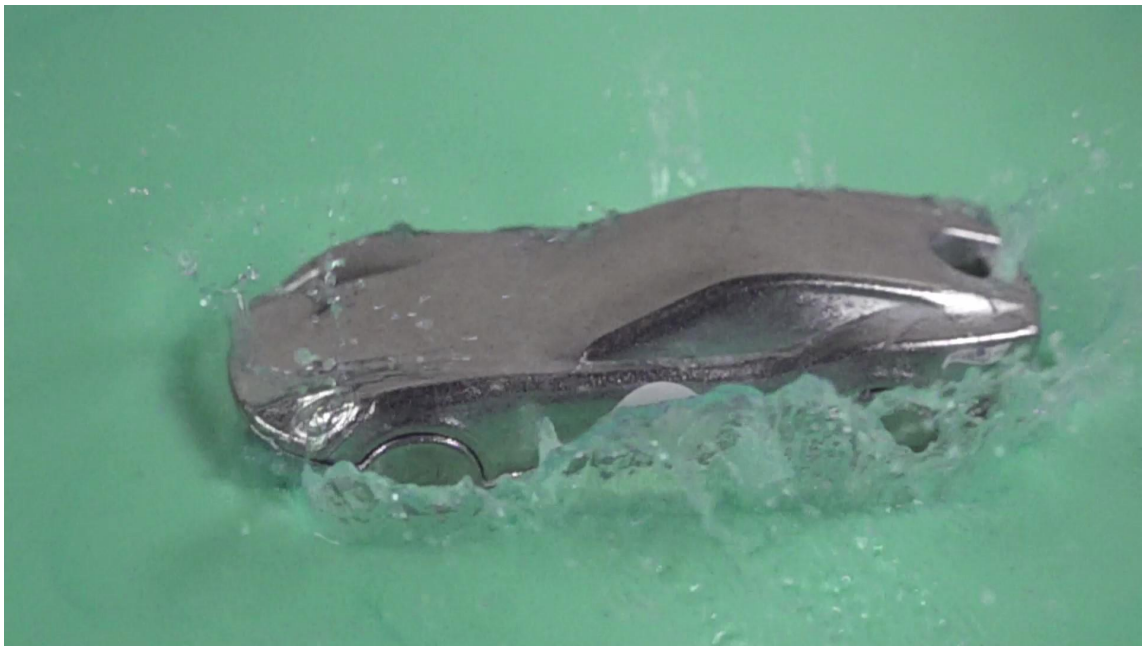

Figure 1, Frame Taken from Subject Video of Model Car Impacting Non-Newtonian Fluid

Introduction

The image above in Figure 1, was taken for the second Image/Visual project in the MCEN 5151, the Flow Visualization course at the University of Colorado, Boulder during the Fall 2022 semester. The purpose of Flow Visualization is to capture and observe fluid phenomena while exploring the interface between art and science [2]. The image in Figure 1 depicts the phenomenon caused by a Non-Newtonian Fluid commonly referred to as “Oobleck”. Non-Newtonian Fluids are classified as fluids that do not behave and react to force in a regular (Newtonian) way. Most commonly, their reactions to shear force and impacts are distorted and cause unusual effects, such as the one depicted in this project. This experiment was conducted indoors in front of a white background with LED lighting with collaborators Will Dietz, Kelsie Kerr, and Meredith Stading.

Fluid Physics

A Non-Newtonian Fluid acts and reacts to outside forces differently than a Newtonian Fluid. Newtonian Fluid behavior is characterized by the applied shear stress and rate of shear equation given below [1]:

$$\sigma_{yx} = \frac{F}{A} = \eta\dot{\gamma}_{yx}.$$

Figure 2, Equation of linear relationship between applied shear stress and rate of shear, Eq. 1.1 from [1]

The equation in Figure 2 describes how a Newtonian Fluid will react to applied shear stress linearly, as almost all fluids do. This means that the more shear stress, or more force, applied to a liquid, the more it will deform or move. A Non-Newtonian Fluid does not follow this equation. While there are many different types of Non-Newtonian Fluids, the focus of this experiment is Shear Thickening Fluid. This type of fluid is resistant to sudden impact forces but will flow with slow, gradual forces. Oobleck is a mixture of cornstarch and water and, "when an impact load is applied the grains of cornstarch lock into positions due to rubbing against each other" [3]. The resistance to impact in Oobleck is due to the friction forces of cornstarch molecules in shear loads.

The model car used is 3 inches long and 1 inch wide, weighing approximately 1 ounce or 0.0625 lbs. It was dropped from about 8 inches (0.75 feet) above the bowl of Oobleck. Using the equation for free falling velocity change and impact force, the impact force is found below:

$v_f^{\,2} = v_i^{\,2} + 2ah$ where initial v is zero ft/s, a is gravity, and h is .75 feet

$v_f^{\,2} = 2(32.2 ft/s^2)(.75 ft)$

$v_f = 6.95\ ft/s$

$F_{impact} = (.5 * m * v_f^{\,2})/h$ where F_impact is impact force, m is 0.0625 lbs, and h is .75 feet

$F_{impact} = (.5 * 0.0625 * 6.95^2)/.75 = 2.01\ lbf$

Based on the above calculations the model car hit the surface of the Oobleck with a force of 2 pounds. The Oobleck resisted this force, causing the car to bounce off the surface before returning down and slowly sinking down over the rest of the video. One effect of note is how the Oobleck settled in the bowl over the time of the experiment causing a splash of water at the initial impact of the car. This effect gave a better feel of impact to the experiment and so was left in.

Visualization Technique

The visualization techniques in this experiment were adjusted throughout but the final set up worked well. This video was taken indoors, with a white bed sheet as the background and clear glass bowl used to hold the Oobleck. The Oobleck was made with a 2:1 ratio of cornstarch to water with green and blue food coloring added during mixing. The camera was placed very close to the surface of the Oobleck with lighting coming from 3 sources, 3 IFB576 LED Lights with stands set at 5600K temperature. The experiment required a lot of takes but after 10 takes the perfect two were obtained, from different angles.

Photographic Technique

This video was taken with a Sony HXR-NX80 Full HD High Speed Camera, shot at 960 frames per second. The distance from the object impact to the lens was about 2 inches and the field of view was about 45 degrees. The video editing included slowing down the video by 50% for a presentation of 1920 frames per second, however no edits were made to the color or cropping of the video. The music used in this video is:

Children by Alex-Productions https://soundcloud.com/alexproduction…
Creative Commons — Attribution 3.0 Unported — CC BY 3.0
Free Download / Stream: https://bit.ly/3qg6PQt
Music promoted by Audio Library https://youtu.be/MEX4G7sfZq4 (This format is used to give proper credit to the artist)
The total time for the experiment to occur, within the video, is a meer 12 seconds despite the length due to the slow motion and high frame rate effects.

Image Conclusions

Non-Newtonian Fluids occur throughout our daily lives from honey to unusual and fun experiments such as Oobleck. This video aimed to show the beauty in something unpredictable like Oobleck. The model car, a common object, approaches a body of fluid with the expectation to sink into it immediately, but instead bounces off of the fluid then slowly sinks. It showed a grand sudden excitement of impact followed by a slow sinking into the abyss of the green Oobleck. There is beauty and excitement in the unusual fluids in every environment, and these should be explored and make any person curious about their own environment.

References

[1] Chhabra, Rajendra P. "Non-Newtonian Fluids: An Introduction." *SpringerLink*, Springer New York, 1 Jan. 1970, https://link.springer.com/chapter/10.1007/978-1-4419-6494-6_1.

[2] Hertzberg, Jean. "SYLLABUS MCEN 4151/5151/ FILM 4200/ ARTF 5200/ ATLS 4151/5151 Flow Visualization: The Physics and Art of Fluid Flow Fall 2022." *FLOW VISUALIZATION A Course in the Physics and Art of Fluid Flow*, 18 Aug. 2022, https://www.flowvis.org/wp-content/uploads/2022/08/syllabusF22.pdf.

[3] Krishna, V. Siva Rama, et al. "Experimental Evaluation of Impact Energy on Oobleck Material (Non-Newtonian Fluid)." *Materials Today: Proceedings*, Elsevier, 23 Feb. 2021, https://www.sciencedirect.com/science/article/pii/S2214785320408302?casa_token=XcpgmNXdcYUAAAAA%3A0wRaInZS-UOL_2OE2t_cKqD-APKrXZRHX6ri8WImiSA-3ZqORTehKegS7ck0QAgvZOzxrkoBXys.