Team Image Report 2

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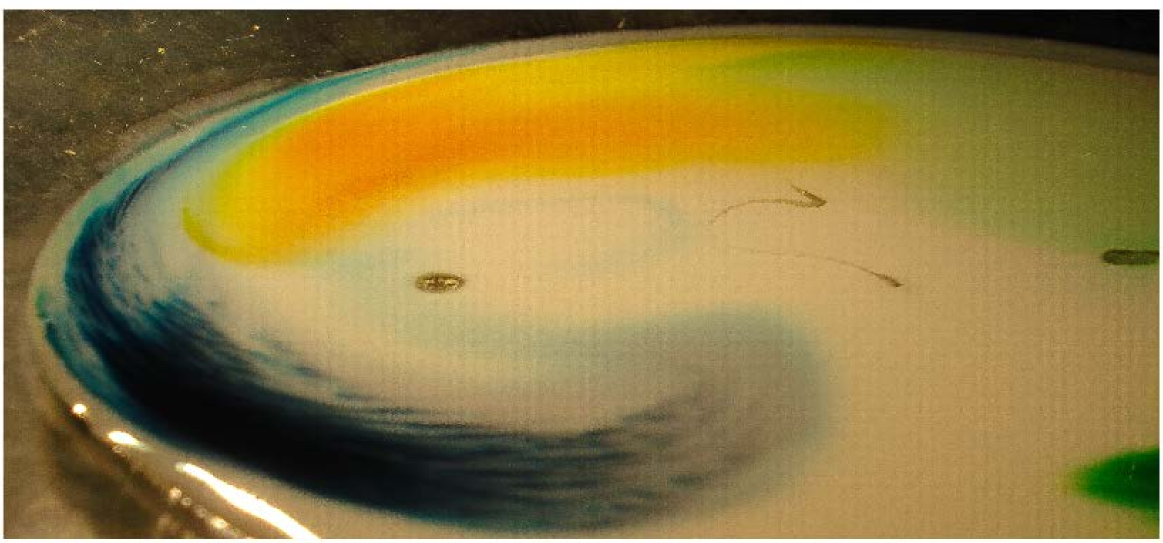
MCEN 5151

Flow Visualization



The Flow Visualization class at the University of Colorado is a course where students learn about flow dynamics and photography techniques by capturing photos of fluid phenomenon. The fourth assignment in the class involved a group of four to five students working in a team to capture a complex dynamic flow by working together. For this assignment, the photographer -- Joshua Hecht-- was placed on a team with Mitch Stubbs, Hamed Yazdi, Ernesto Grossman, and Sam Sommers. The team determined that an apparatus should se set up that would allow for still, colorful photographs, since the previous team assignment involved more “flow” than “artistic” merit with a high speed video. Therefore, the team agreed that food coloring and milk should be used to get the highest degree of contrast between the background and the colorful dyes. The bowl was rotated slightly after the dye was added, which caused the dye to spread out around the edges of the bowl. To achieve a flow with this colorfully spread dye, the team decided to add in soap to the middle of the dyes. The soap addition caused the surrounding layer of milk and dye to quickly disperse from the spot where the soap was injected. A photograph was taken when the soap had repelled the dye and milk to its greatest extent, meaning the milk and dye were no longer moving. The resulting shape of the dye and the milk allows for fluid dynamic analysis.

The dyed milk apparatus was set up fairly simplistically. A clear dish was filled with a half centimeter of one-percent fat milk. A drop of yellow, blue, and green food coloring were dropped in a triangular formation, with about one inch of space between each of the colored portions. The dish was quickly rotated one quarter of a circle, which caused the dyes to rotate and spread out on the surface of the milk. Once the dyes had stopped moving, two drops of Dial® soap were put in the center of the three dyes. This caused the dyes to expand out an additional inch, but the motion stopped after a couple of seconds. Once the surface of the milk was steady, the image was captured. A visual representation of the overall setup is shown in Figure 1.

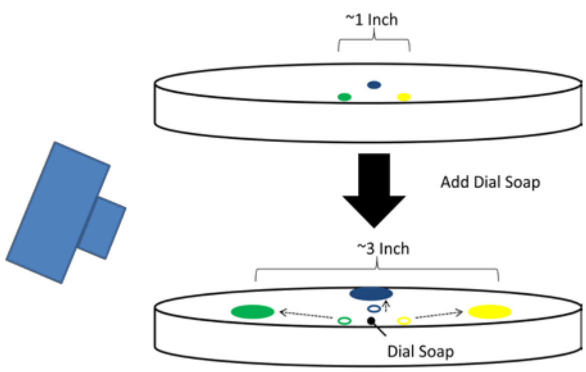


Figure 1: Experimental Test Set Up

The motion of the dye is primarily due to a surface tension breakdown due to the interaction of the milk and the soap. (Furse, 2011) The soap is classified as a surfactant, meaning that it lowers the surface tension of the liquid it is in contact with. (Rosen, 2012) A surfactant is made up of organic compounds that are both hydrophobic (repels water) and hydrophilic (attracts water) depending on the orientation of the compound. (Rosen, 2012) This makes soap an extremely effective cleaning agent, because it is both water and non-water soluble, depending on the environmental conditions it faces.

When the soap is exposed to the milk, the hydrophobic side (the tail of the compound) is not very effective, since water is primarily composed of water. On the other hand, the hydrophilic side (the head), is in a favorable condition by being surrounded by milk, and positions itself so as to reduce the exposure of the hydrophobic side to the water. (Furse, 2011)

To reduce the hydrophobic tails' exposure to the milk, the surfactants position themselves together to create a spherical formation with the heads on the outside and the tails on the inside. (Furse, 2011) This effectively reduces the amount of exposure the tails experience, and protects the hydrophobic side from the milk. (Furse, 2011) A diagram of this formation is shown in Figure 2:

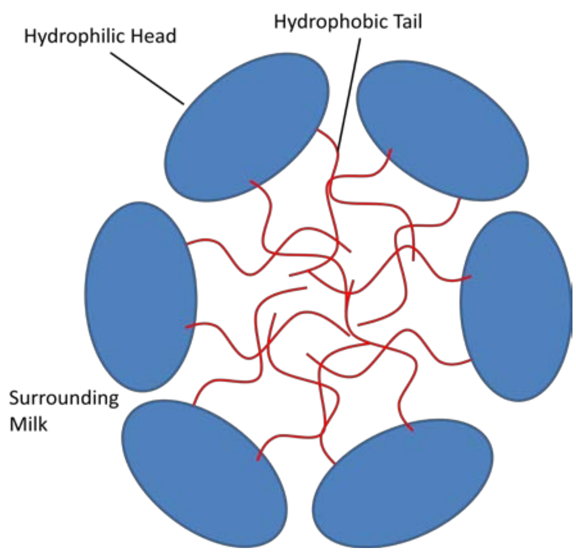


Figure 2: Soap Surfactant Configuration in Milk

This configuration has one significant effect upon the milk: it breaks up the chemical bonds when exposed to the surface of the milk. (McGillivray, 2003) The chemical bond breakdown occurs when the surfactant spherical configuration is pushed above the water line so that a portion of the sphere is in the air. When a portion of the spherical configuration is in the air, the hydrophobic tail is exposed to the milk. The alignment changes the physical properties at the surface of the milk, most notably by reducing the surface tension on the milk. This occurs due to adsorption at the milk/air interface. (McGillivray, 2003)

Adsorption is essentially the adhesion of molecules onto another surface. (Cussler, 1997) In this case, the fat molecules on the surface of the milk begin to adhere to the hydrophobic tails, since fat molecules are hydrophobic as well. (McGillivray, 2003) The this fat molecule separation causes a difference in composition between the milk on the surface and the milk below, since the milk below has not been adsorbed and the milk above has. (Cussler, 1997) The difference in composition causes a reduction of surface tension. A reduced surface tension makes it less likely for the milk to stick to itself, allowing the surface of the milk to flow so quickly when soap is added. (Furse, 2012)

With this in mind, more fat within the milk would react stronger with the surfactants in the soap. A higher fat percentage milk (say, whole milk) would likely have caused a quicker reaction, with the dye moving outwards faster, since the higher concentration of fats would encounter the hydrophobic tails more often. However, it is doubtful that the dye would have moved much further than it did in the experiment with two-percent milk, since the same amount of soap based hydrophobic tails would have been saturated with the same amount of fats, regardless of the fat concentration of the milk.

This hypothesis arises from comparing the initial motion of the milk when the soap was added, to the motion of the milk a few seconds after. The dye moved away from the soap quite rapidly when the soap was first added, but the dye stopped moving a few seconds after the soap was added. This would indicate that whatever reaction was occurring between the soap and milk had ceased. It is possible that the hydrophobic tails of the surfactants initially absorbed fat molecules extremely quickly, causing the first burst of surface tension breakdown. As the fats adhered to the tails, there was less surface for the rest of the fats in the milk to adhere to, which slowed, and eventually stopped the surface tension breakdown. Therefore, the amount of soap in the water was the limiting factor, not the concentration of fats within the milk. This could easily be verified with a set volume of soap and milk, while varying the fat concentration in the milk.

It should be noted that the dye itself did not react with the soap in the experiment. The movement of the dye was essentially just a representation of the dynamics occurring between the soap and the milk.

In terms of visualization scale, the smallest viewable flow phenomenon was approximately five pixels across. The entire field of view for the flow phenomenon in the photograph is 3072 pixels. Therefore, with the following equation, the scale of the resolution can be determined:

$$Resolution = \frac{Entire\ field\ of\ view}{Smallest\ viable\ flow}$$

$$Resolution = \frac{3072\ pixels}{5\ pixels} = 614.4$$

$$Resolution = 6.14e2$$

Therefore, since the resolution is in the hundreds, the scale of resolution is two decades, which is well resolved for the flow shown in the video.

When it came to capturing the flow itself, the visualization technique was fairly simple. An eight inch clear, circular dish was filled up with approximately a half centimeter of milk. Blue, green, and yellow dye were dropped in at equal distances from one another, and were spread out on the surface of the milk by giving the dish a one-quarter circle rotation. The soap was dropped in the center of the dyes, and was allowed to react to completion. The camera was lined up slightly above the surface of the milk, with a ~30 degree downwards angle from the horizontal. The lighting source was from a high powered lamp pointing directly at the milk from above and away from the angle of the camera.

The photographic technique involved setting a suitable ISO, focusing the lens for a wide depth of field, and holding the camera still while taking the photo. The depth of field allowed for the dyes themselves to come out in sharp focus, though the dish and dyes closer to the camera are out of focus. This depth of field blurred out a good portion of the bowl and the lower portion of the dye. However, this worked out fairly well, because the depth of field forces the viewer to concentrate on the middle of the photo, where the soap is interacting with the milk, rather than the residual dye results on the side.

The picture was taken at an ISO of 100, a focal length of 6.3 millimeters, an f stop value of 7.1, and a shutter speed of 1/400 seconds. The image was captured in jpeg format with 7.1 megapixel resolution (the maximum resolution for the Sony Cybershot DSC-S700) with a width of 2304 pixels, and a length of 3072 pixels. The original image can be viewed in the Appendix. The picture was cropped down to 2304 pixels by 2418 pixels, and Photoshop Lightroom© was used for editing. In editing, the contrast, brightness, and saturation were largely unchanged. However, there were significant changes in the sharpness of the photograph, since the image was sharpened by 75. This significantly changed the image, for the image ended up looking very grainy in some places, and gave the photograph a “canvas” texture look. This was not the intension, since it takes a lot of the sharp focus out of the photo, but as the professor noted, it gives it an artistic feel, since you don’t generally see any photos with a “canvas” texture.

Overall, the image reveals interesting dynamics of a very common fluid interaction between soap and fats. The dye helped the team to visualize what exactly happens between the milk and the soap as the two are allowed to mix. The spreading of the dye and the dynamics of the milk and soap allowed the dye to come out as a galaxy looking shape, which was something that I was quite pleased with. I also like that the shot shows a steady state condition between milk and soap, as opposed to catching a flow actively in motion. I still would like to know if it was the concentration of milk or the concentration of soap that caused the milk to stop moving. I In the future, I would like to conduct a series of shots comparing different concentrations of milk fat, to see how the flow changed with each shot. Also during Photoshop®, I wish I had not sharpened the shot so much, since the overall picture ended up looking much more “textural” than I wanted it to. In the end, I feel that I learned quite a bit from this project, and that I finally figured out how soap works when cleaning off my dishes/hands.

Bibliography:

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Appendix:

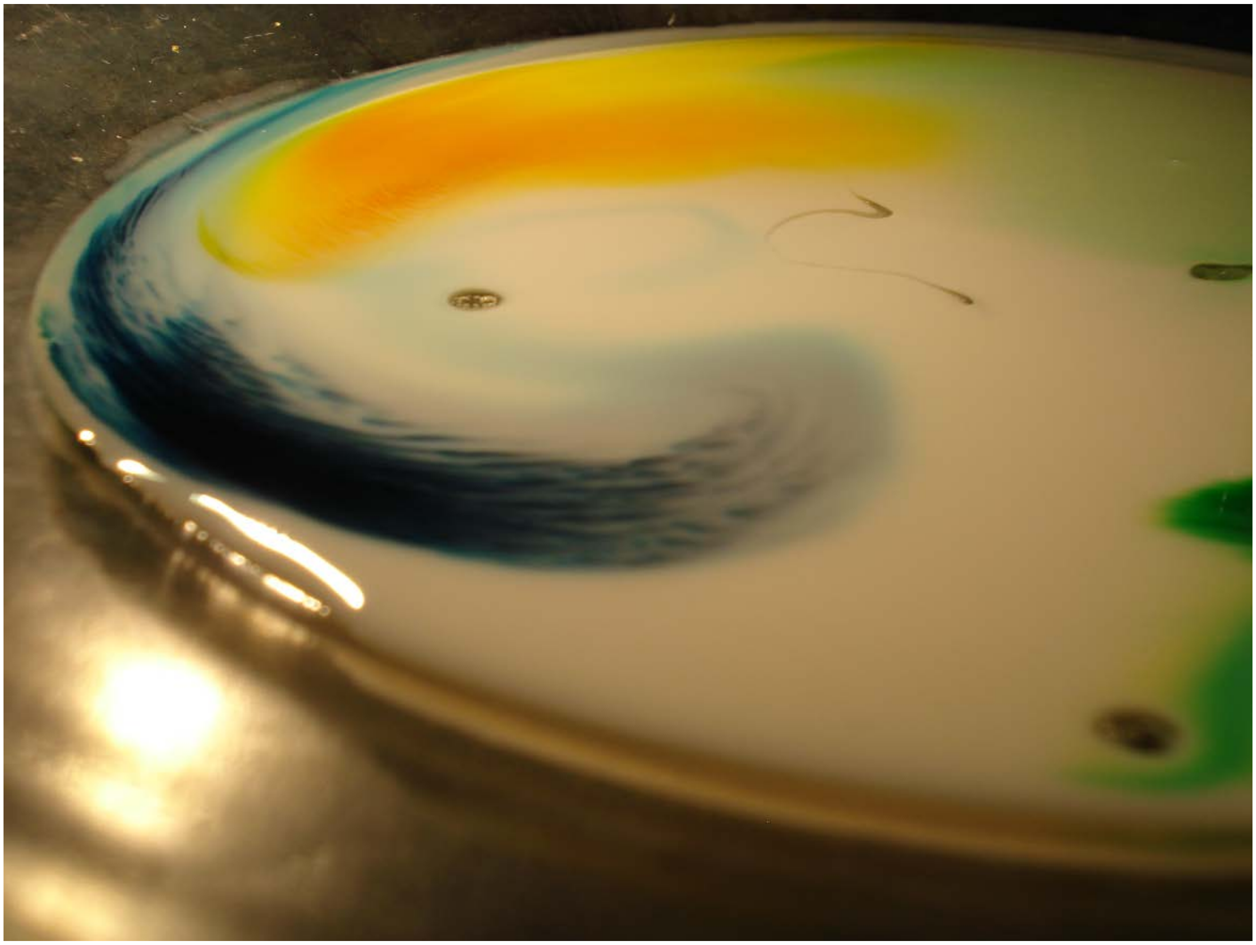

Photo with no edits