Flow Visualization: Team Image #3 Report

     The image above is a submission for the spring semester of Flow Visualization's third team based image assignment. In the previous team assignments, I ultimately worked alone. However, in this case, I worked with Anthony Johnson. At the time, the normal Sony SLT-A55V DSLR was not functioning, so we utilized his camera instead.   This image captures the fluid flow from milk being mixed in a magnetic stir blender. Various trials included different colors of food dye being dropped into the milk as well as different stir speeds. In this specific case, a red food color dye was used. The mixing illustrates a relatively viscous liquid being mixed at high rotational velocities.

The image apparatus setup included 2% reduced fat milk, the magnetic stir rod, the magnetic blender, and a small glass salad bowl. The milk was first poured into a separate container and allowed to warm up to the room temperature (approximately 21 degrees C). A picture of a magnetic stir rod and the blender can be seen below[1].

Figure 1 - Blender and magnetic stir rod

The milk, as well as several drops of red food coloring was poured into a small glass salad bowl. The bowl had a base diameter of approximately 3 inches and ultimately had almost an inch depth of milk. Once the bowl was placed on top of the stirrer, the stir rod was placed into the center of the bowl and the stirrer was started. The bowl was adjusted slightly on the stirrer to ensure that the magnetic stir rod was spinning in the center of the bowl, and the stir speed was gradually increased. In the case of my image, the stir rod was spinning at approximately 600 rotations per minute. The camera was placed directly overhead, approximately 4 inches from the surface of the milk, and captured the image using ambient lighting in combination with a diffused camera flash. The flash from the camera was "diffused" by adding a tissue paper layer over the flash bulb.

The fluid dynamics most visible in the image associate with viscous fluids in turbulent forces. The milk interacting with the stir rod, especially along the ends, undergo forces that create a small undertow. The milk near the rod rotates outwards and causes the milk in the bowl to convect. Especially, any air caught within the milk from the stirring creates bubbles that move from the center outwards and then to the surface. As seen in the image, the bubbles are only on the outer edges of the surface. However, the longer the system is kept stirring, the more bubbles began to overrun the surface. Before long, air becomes too prevalent and the process must be restarted in order to capture the milk clearly.

The Reynolds number of the milk being stirred can be roughly calculated in order to verify that the flow is indeed turbulent.

$$Re = \frac{\rho V L}{\mu}$$

The density of the milk is approximately 1036.86 kg/m^3. The viscosity of milk at room temperature is 1.9×10^{-3} N*s/(m^2). The characteristic length, L, is 2 inches, or 0.508 meters. The mean velocity was calculated from the RPM to be 3.99 m/s. Once these values are used in the equation, the Reynolds number is evaluated to be 1106073.088, well above the cutoff for turbulent flow (5×10^5). At the revolution per minute used in this image, the milk was in turbulent flow due to the stir rod.

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[1] http://www.labdepotinc.com/c-101-lab-stirrer.php

For future recreation of the submitted image, the same setup can be used. However, future results would be interesting with varying amounts of milk. Also, varying the length and thickness of the magnetic stir rod would be interesting to see.

The original image spans approximately two inches wide by three inches tall. The camera flash capability was used in combination with a tissue paper as previously stated. The camera, a Kodak Easyshare Z981, was located approximately 4 inches from the surface of the mixing milk. A focal length of 10.3 mm was used. Alongside the focal length, an F-number of 3.5, an exposure time of $1/1500^{th}$ of a second, and an ISO of 200 were used. The original, unedited image can be seen below. Its resolution is 3216 x 4288. The final image has a field of view of 3.5 inches wide by 2 inches high.
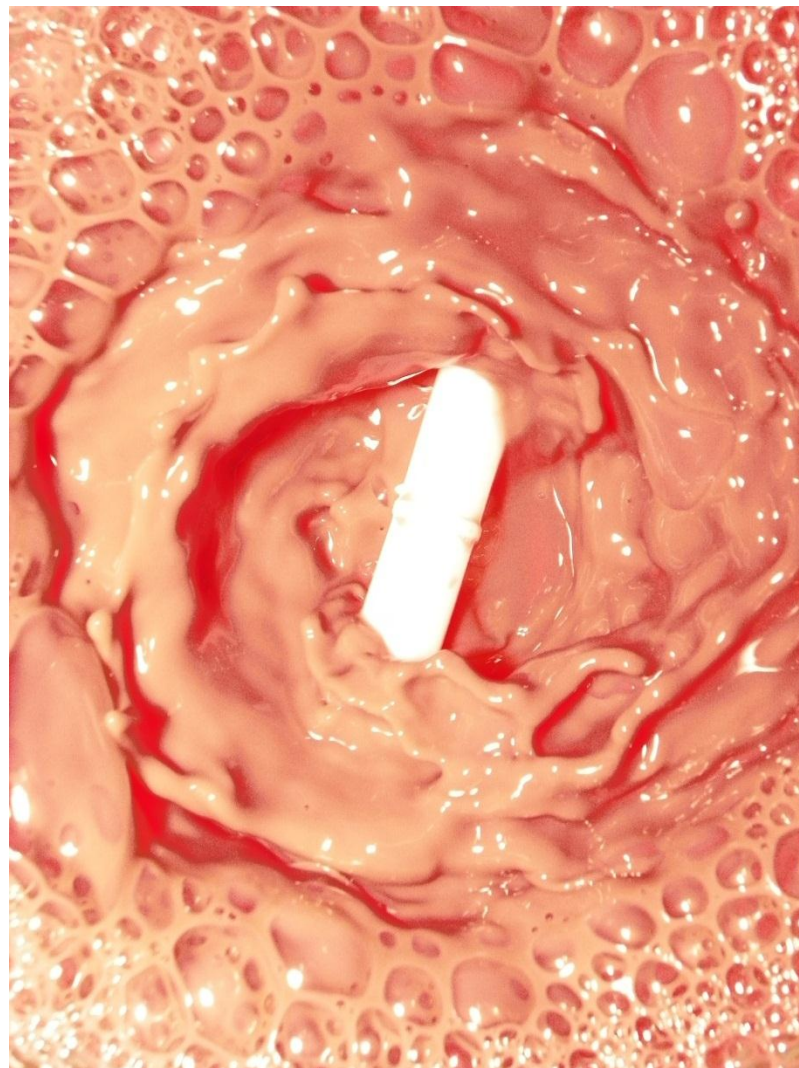

Figure 2 - Original Image

Photoshop was also used to add a few overlay layers that slightly altered the color balance and saturation. Curves and levels were modified slightly, but ultimately, the editing simply changed the colors image to a purple hue.

       In the end, I felt the image effectively portrayed a crossover between interesting fluid dynamics and chaotic imagery. Although there many spots in the image where light is reflecting off of the milk, the curves and shapes of the milk being torn about by the magnetic stir rod are still clear. I think the image has a visible three dimensional feeling to it, in which the depth of the stir rod, milk, and bubbles all clearly differ. Future attempts could be improved by altering the lighting slightly so that there would be less reflection, and also possibly changing the camera angle in order to better show the different depths.

Works Cited.

Density of Milk." *Hypertextbook.com*. Web. 5 May. 2012.
<http://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml>.

"Viscosity of Foods." *Engineering ToolBox*. Web. 5 May. 2012.
<http://www.engineeringtoolbox.com/absolute-viscosity-foods-d_1827.html>.

"Magnetic Stirrer, Hot Plate Stirrir." *The Lab Depot, Inc.* Web. 5 May. 2012.
<http://www.labdepotinc.com/c-101-lab-stirrer.php>.