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**Get Wet Image Report**

This image was taken for the “Get Wet” project, and was done alone. A magnetic stir bar was used in conjunction with a hot stirring plate. The original intent was to capture a vortex initiated in a sucrose ester stearate-in-water solution while the water was at the boiling point. Chemically, the structure of a sucrose ester stearate is similar to a lipid, which is hydrophobic, so extremely high temperatures are required. Ideally, the image would have incorporated bubbles spinning around the central vortex, but even with the ISO turned all the way down, the image was still blurry. Most of the failed images were taken either before the sucrose ester stearate had finally dissolved or while the solution was still boiling; both had produced undesirable qualities in the image. An attempt to mix 90% ethanol with the solution at the boiling point was also made; this caused a violent reaction that entailed explosion-like qualities to occur.

The flow apparatus used in this image was a magnetic stir bar in a beaker of fluid, which sits on a hot plate containing a mechanism to cause the stir bar to spin. The heat from the plate results in a lower viscosity in the fluid, which makes it more compliable to the stir bar. The bar creates a rotational flow in the fluid contained in the beaker that forces larger volumes of fluid to gather at the walls of the beaker. This is a result of the centripetal force that occurs during rotational flow. The tangential velocity of the flow of the vortex is represented by the following equation [3]:

$$v_\theta = \omega r \qquad (1)$$

Where:

$$\omega = angular\ velocity$$

$$r = radius$$

The magnetic stir bar was spinning at approximately 1000 rpm, which is approximately 16.67 rotations per second. The angular velocity of the outside wall of the vortex (from inspection) seemed to be approximately 3 rotations per second (6pi radians per second). The radius of the vortex was approximately 1.5 cm (0.015m). The tangential velocity of the vortex comes out to be approximately 0.2826 m/s. Using this, we calculate the Reynolds number, which can be modeled by the following equation [1]:

$$Re = \frac{\rho V D}{\mu} \qquad (2)$$

Where:

$$\rho = density$$

$$V = fluid\ velocity$$

$$D = diameter$$

$$\mu = dynammic\ viscosity$$

The density of the glucose solution was approximately 0.05 Pa*s, the dynamic viscosity is approximately 0.00131 Pa*s, the diameter is 88 mm (.088 m). The fluid velocity (as found in the previous calculation) was 0.2826 m/s. The calculation gives us a Reynolds number of 0.9491. This value seems low, despite wanting to maintain a non-turbulent flow to avoid the occurence of unwanted microbubbles. The ultimate use for the solution would be for the generation of microbubbles, but since a very discrete diameter of bubble is desired, a homogenizer that operates at very specific RPM would be required. Had any microbubbles appeared in the solution, the operator would simply have to wait until the oxygen in the bubbles completely diffused out, which would cause cavitation and thus, destroying the bubbles and returning the sucrose stearate to the solution. The equation to model the reduction in radius of the bubble over time is [2]:

$$-\frac{dR}{dt} = \frac{L_g}{\frac{R}{D_w}+R_s} * \frac{\left(1+\frac{2\gamma}{P_A R}\right)-f}{1+\frac{4\gamma}{3P_A R}} \quad (3)$$

Where:

*R=radius of the bubble*

*Rs=gas permeability resistance of the shell*

*Lg=Ostwald coefficient*

*γ=surface tension*

$P_A$*=atmospheric pressure*

And f and $D_w$ are constants based on the material properties.

Regarding visualization techniques, no solid color backdrops were used in this image to optimally utilize the reflective properties of the surface of the vortex. The only thing is a slight discoloration in the water that occurs due to the sucrose stearate mixed in. Some extra lighting (a lamp containing a fluorescent bulb of 40 watts) was arranged to provide a better illumination of the background, but none was applied directly to the subject to avoid glare on the glass. The solution consisted of DI water (which was created on site with a filtration system) and 10 mL of sucrose stearate powder (which was provided by Fisher Scientific). Aside from the lamp, just the ambient light was used from the overhead fluorescent tubes. The flash was suppressed in order to prevent glare.

The field of view was approximately 5.5 cm and the distance from the object to lens was approximately 9.5 cm. The lens focal length was 19 mm with an ISO speed of ISO-400. The exposure time was 1/100 seconds and the max aperture was 3.4375. A Sony DSC-W180 digital camera was used to capture the image. The pixel width x height is 2736 x 3648. Photoshop was used to increase the contrast by 15% as well as apply a cooling filter.

Artistically, I did not make this image to tell a story or portray a message; I created it to convey a feeling of relaxation and tranquility. The name "Misty Blue" goes hand in hand with the color scheme. Despite not being able to accurately capture the miniature bubbles caught in the cyclone due to boiling, I feel the image was largely successful. The limiting factors in this image were definitely due to equipment quality. While the physics of boiling water being caught in a rotational field couldn't be captured for this project, I am satisfied with the image that resulted. The physics behind the cyclone are represented very well in that it clearly shows the boundary of the fluid as well as the vortex lines. It is interesting to look at and the modifications in Photoshop definitely compliment the image. In the future (and with a better camera), I feel that it would be interesting to add ethanol to the boiling solution and capture the point in time where it causes the solution to react as well as generate bubbles in the solution due boiling of the ethanol.

**References:**


1. Cengel, Yunus A., and John M. Cimbala. "4, Streaklines." *Fluid Mechanics: Fundamentals and Applications*. Boston: McGraw-Hill Higher Education, 2010. 133. Print.

2. Dressaire, E., Bee, R., Bell, D.C., Lips, A. & Stone, H.A. Interfacial Polygonal Nanopatterning of Stable Microbubbles. *Science* **320**, 1198-1201 (2008).

3. Hibbeler, R. C., and Peter Schiavone. "12, Curvilinear Motion: Cylindrical Components."*Engineering Mechanics: Dynamics*. Upper Saddle River, NJ: Pearson/Prentice Hall, 2007. 63. Print.