“Get Wet” Image Report

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This image was taken and selected for the “Get Wet” project in the Mechanical Engineering Course “Flow Visualization”. The goal of the image is was to photograph the instabilities that arise when a small amount of ink or food coloring is added to the surface of cold still water and begins to sink downward. To capture this phenomenon I first attempted to use various colors of standard food coloring, but I found that when using food coloring the details and fine structure of the instability were hard to see and visualize by camera. This problem was resolved by replacing the food coloring with a specialty ink that is normally used for calligraphy or in fountain pens. This seeding technique using ink produced much more visible detail and allowed for superior images to be made.

To produce this image only basic materials and lighting was necessary. The water was contained inside a rectangular glass flower vase measuring approximately 10.8 cm”x7.0 cmx15.25 cm with clear undistorted sides and was filled with tap water which was allowed to settle for approximately five minutes to help ensure any flow caused by the filling process had ceased. The vase was placed on a tabletop with a white cotton cloth used as a backdrop. A halogen lamp was held approximately two inches above the water surface to highlight the color of the ink against the white backdrop. The ink used was Noodlers™ Air-Corp Blue Black fountain pen ink. I found this ink to be superior to both the food coloring as well as Parker™ brand Quink™ ink in regards to definition of the amount of instability observed and the quality of images that it produced.

The instability seen from the flow of ink in water shows the characteristic properties of a Rayleigh-Taylor Instability. This instability is caused by the boundary layer between the water and the heavier ink. As the ink initially sinks downward it begins to form columns which have small dimple like deformities. As the flow continues to evolve these dimples expand into finger like instabilities, which then evolve into the small vortex rings present near their respective bottoms. To ensure that the flow in fact can go unstable a quick estimation of the Reynolds Number is useful. The Reynolds Number of a fluid can be calculated using the equation below [1]:

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

where ρ is the fluid density, the V is the fluid velocity, L is the characteristic fluid length, and μ is the viscosity of the fluid. In this experiment some of these values are known exactly, such as the density of the water.

$$\rho = 1000\,\mathrm{kg/m^3} \text{ (estimation)}$$

$$\mu = 8.90\mathrm{x}10^{-4} \text{ Pa s}$$

$$V = 0.05 \text{ m/s (estimation)}$$

$$L = 0.5 \text{ m}$$

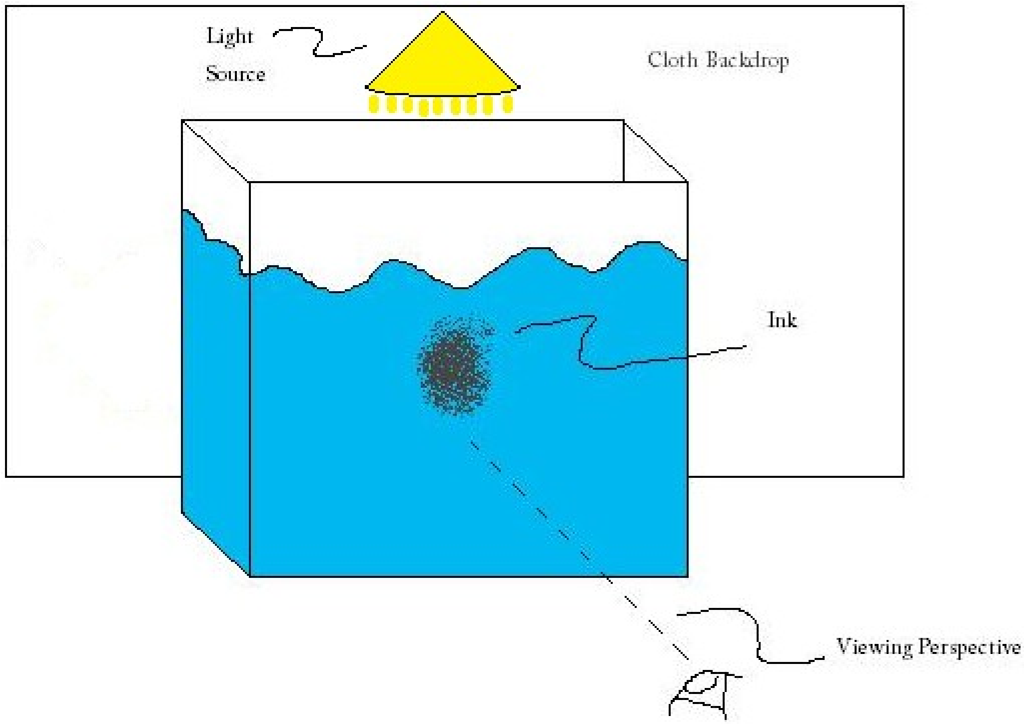
Plugging in these values we obtain a Reynolds Number of 28,090, such a value puts this fluid flow clearly into the regime where instabilities can arise. The estimations made are due to the fact that accurate data on the physical properties of the specific ink were not available so the properties of water were used instead.

For this image a Canon Rebel Xsi digital SLR was used with a Canon 55-250mm 3.5:5.6 EFS lens. The photograph was shot at 250mm and f/ 5.6 from a distance of approximately one meter from the flower vase. An ISO setting of 100 and a shutter speed of 1/60 s to preserve the quality of the image and reduce as much noise as possible. To improve the visibility of the flow and increase definition in the edges I used Photoshop CS3 to both change the image to black and white, and to increase the contrast. The width of the frame is that of the entire vase 10.8 cm, which is important when attempting to make measurements of the flow.

Overall I am pleased with the outcome of this image, though I also feel that there are improvements that could be made in future attempts. I am pleased with the ability to capture the entire fluid flow, with plenty of space to spare at the borders. With the increased contrast the visibility of the ink seeding the water is both informative and aesthetic. In hindsight I would want to increase the shutter speed in future attempts, either by increasing iso or adding additional light sources around the ink flow. The other improvement I would want to try is the addition of macro spacer rings to my camera to allow the flow to take up more of the frame and reduce the minimum focusing distance of my lenses. Using these improvements I would hope to be able to capture the detail of the instability of the ink in further into the flow, as with the current set up the resulting images from later times in the flow were harder to interpret.

<u>Appendix</u>

A schematic of the apparatus used is shown below.



References:

[1] http://www.grc.nasa.gov/WWW/BGH/reynolds.html