Spring 2018: Get Wet

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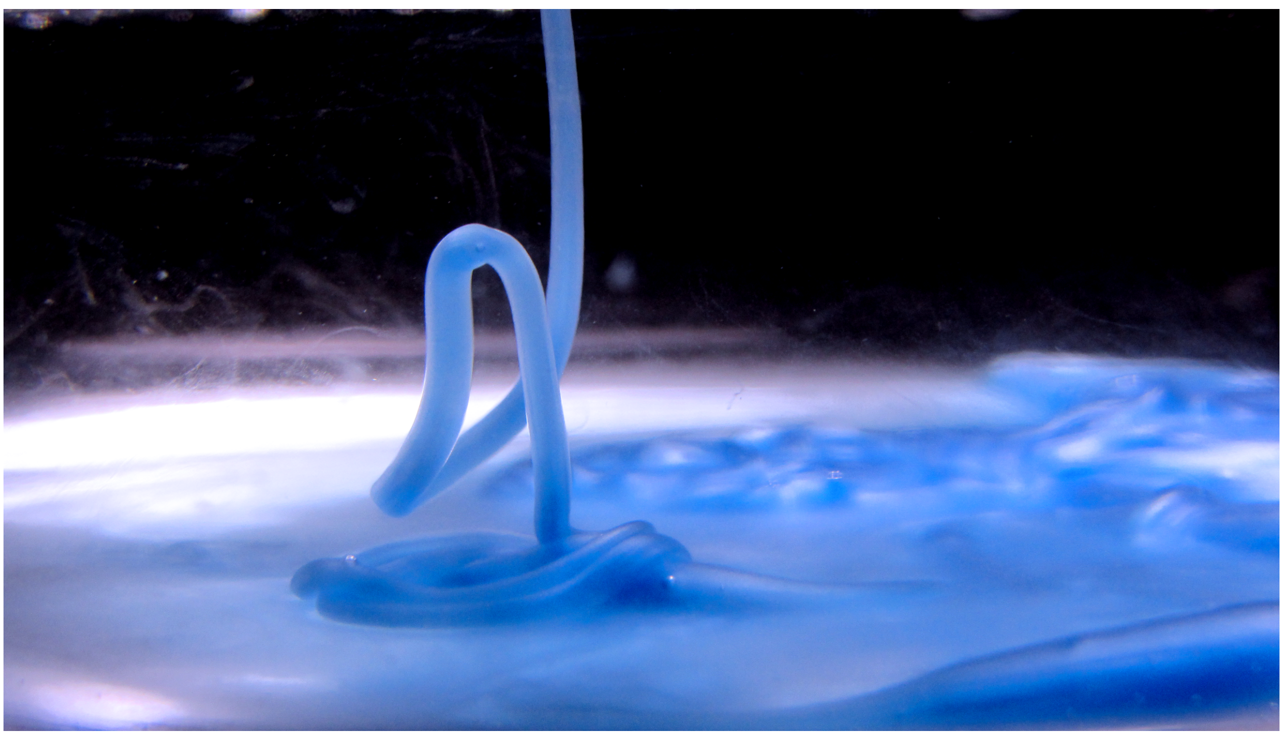

“The Blue Loop”

Introduction

The image below, which I have titled "The Blue Loop" was submitted for review and critique in the Spring 2018 Get Wet assignment for MCEN 4151: Flow Visualization, the Physics and Art of Fluid Flow on February 5, 2018. This image was the result of numerous attempts, in a trial and error method until the desired aesthetic was achieved. That being, the image was attempting to capture what is known as the "rope-coiling" effect underwater (explained in further detail below) and ended up turning out better than expected. This image was created as a result of my own handiwork, and I received no assistance in its production.

Flow Apparatus

The flow in this image consists of a stream of dense blue liquid falling through and resting at the bottom of a glass bowl filled with water. As the blue liquid fell the resulting "rope-coiling" occurred. The process by which the desired effect occurred is shown in the schematic below.

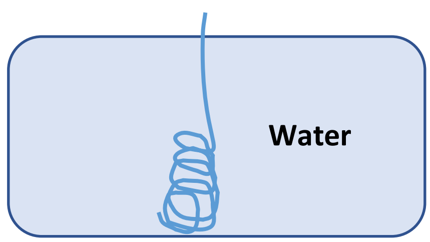

Figure 1: Schematic of rope coiling in water bowl

In the liquid rope-coil effect, a thin stream of vicious fluid falls and forms a steady, rotating, helical coil. Normally, in this effect, the coil is seen to stack onto itself, and 'climb', however upon inspection of my image, it can be seen that this does not exactly occur as one would expect. Instead, the pressure and weight of the water likely affected the maximum height to which the stream could coil. This created an effect where the stream simply laid on top of itself, slowly adding layer by layer, instead of rapidly climbing in a tight coil, as would be expected in an air environment. Generally speaking, rope-coiling is a form of an instability, that deforms by gravity-induced bending and stretching. These streams, including the one in the produced image are subject to the forces of gravity, inertia, and viscous forces. [1]

It is important to note and distinguish a unique element of the flow in "The Blue Loop", which is the loop itself. When the blue liquid was falling towards the bottom of the bowl, when it passed through the surface of the water, it created bubbles in the stream (likely due to its higher surface tension). As gravity and the weight of the blue fluid pulled the stream down, eventually, the trapped bubble added an additional force, buoyancy, to the mix.

As the stream of blue liquid is assumed to be laminar, one can calculate/estimate a Reynold's number, *Re*, for the downward laminar flow:

$$\boldsymbol{Re = \frac{UD}{v}} \tag{1}$$

Where *U, D*, and *v* are the flow velocity, diameter of the stream, and viscosity of the fluid, respectively. In the image produced, the blue stream was Irish Spring® Moisture Blast™ Body Wash (see Appendix A). While it is difficult to determine an exact viscosity of this fluid, I estimated it using the viscosity of water (obviously a simplification), In reality the kinematic viscosity would be altered most by second-most-present ingredient in the body wash (behind water), sodium laureth sulfate. This chemical is a detergent and surfactant (lowers surface tension) commonly used in many personal hygiene products. The estimated dynamic viscosity is in a range between 3000-7000cP [centipoise]. Assuming that the diameter of the stream is about 3mm, and assuming that the velocity was a constant 1cm/s, the estimated Reynold's number is equal to 30, which, albeit a bit low, is well within the laminar range (<2000) and is consistent with the observed behavior.

Visualization Technique

This image was created using a glass bowl filled with approximately 2 cups of fresh water. The blue stream was Irish Spring® Moisture Blast™ Body Wash liquid, poured slowly (at a rate of about 1cm/s) from a height of approximately 40cm from the surface of the water. Lighting was provided by two desk lamps, diffused with paper bags, and no camera flash was used.

Photographic Technique

"The Blue Loop" was created using the following specifications:

- Field of view: approximately 6"x3"x4"
- Distance of first object from lens: The bowl was located about 1.5" from the camera lens, and the blue stream was about 0.75" further back from the inner rim of the bowl.

- The camera used was a Canon® PowerShot™ SX530 HS. A digital point-and-shoot camera, with an original image capture size of 4608x3456px. A final image size of 4608x3456 was used.
- Exposure specs: camera defaults were used on automatic settings.
- All post-processing was completed in Adobe Photoshop CS2. Image colors and saturation boosted (blue levels). Black sections darkened and contrast was increased.

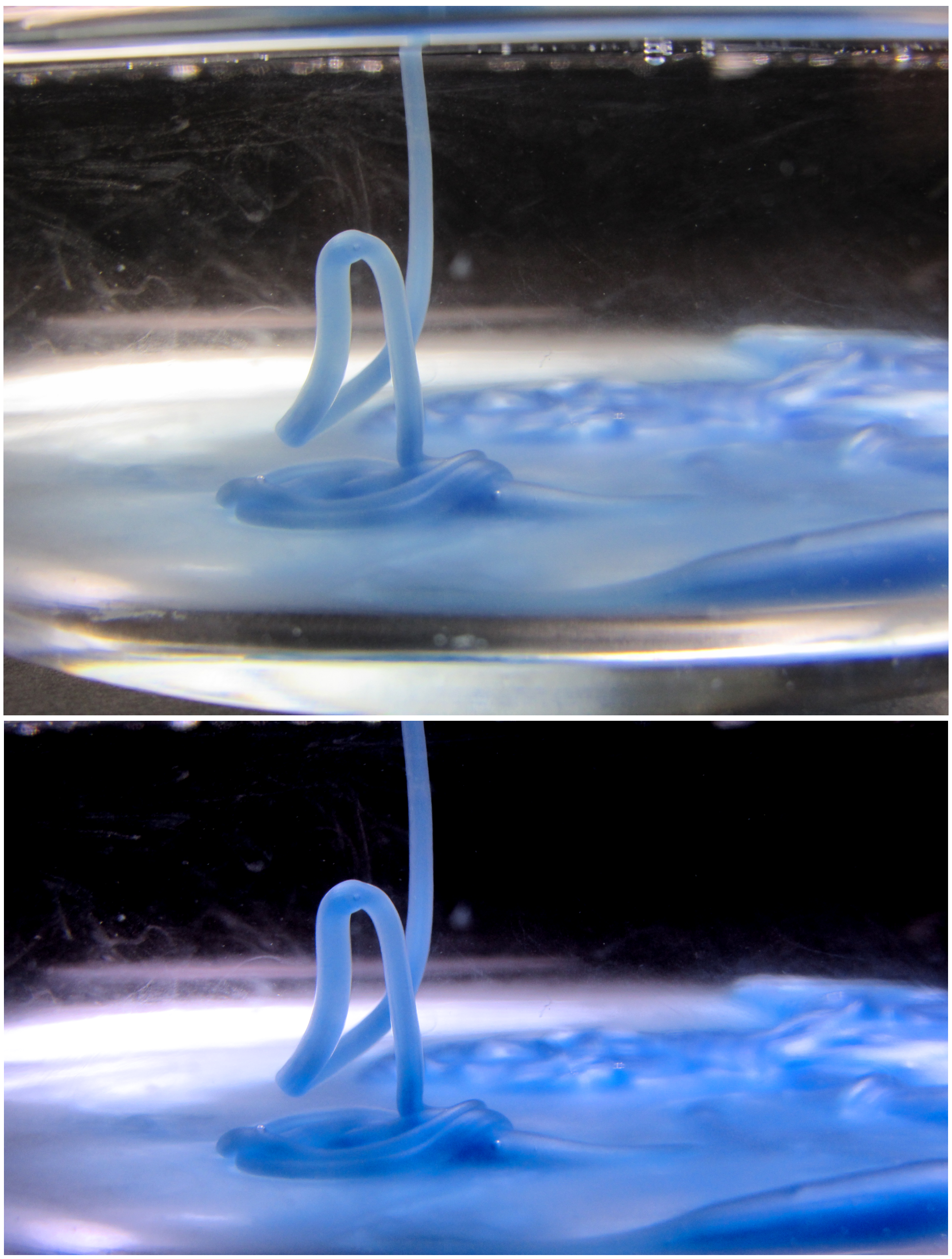

Figure 2: (From top to bottom) Original and final versions of “The Blue Loop”

Conclusion

This image reveals the rope-coiling instability, as well how hydrostatic pressure and buoyant forces affect flow of more viscous fluids through water. I like the abstract quality of the image, and how at first glance, it appears as though the blue stream creates a physically impossible shape, a loop. Upon further inspection, the bubble, ever so small, provides just enough upward force to suspend the stream in the water. In the future I'd like to improve and be more mindful of the use of my camera equipment, in order to get full control over the image. Perhaps, I could also experiment using different fluids to try and replicate the loop-like effect.

Works Cited

1. Ribe, N. M., Habibi, M., & Bonn, D. (2012). Liquid Rope Coiling. *Annual Review of Fluid Mechanics,44*(1), 249-266. doi:10.1146/annurev-fluid-120710-101244