Get Wet Report

MCEN 4151: Flow Visualization

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9/25/23

Figure 1: Gelatin wrinkles on the surface of colored water. Photographed by Riley Menke, assisted by Maddie Leaver

Introduction

For this assignment in MCEN 4151 at the University of Colorado Boulder, the objective was to 'get my feet wet' in the vast discipline that is flow visualization. I decided to focus my attention on the various changes in density that happen to the aqueous solution in the process of making gelatin. Despite initial intentions, I became interested in the surface changes that happen visually right after gelatin is added to cold water. I was able to capture the picture in Fig.1 with the help of Maddy Leaver pouring the packet of collagen based flavorless gelatin into cold tap water in a pie dish.

Flow Phenomena

In the same Fig.1 the interest of the photo lies in the solution's surface that has 'wrinkly' features. The physics equation that drives this visual is quite simple, however the chemical breakdown of this event is slightly more in depth. To understand how the wrinkles on the surface of the water are formed, one must first understand the behavior of gelatin's chemical compounds. The gelatin used is collagen based. From collagen, the protein that characterizes Jello's properties, is derived through different manufacturing methods[1]. After this process, the derived protein in gelatin powder undergoes partial hydrolysis. To restate, the protein in collagen has been broken down in such a way that it is ready to bond to both an acid

or a base. In this experiment, the compound undergoes partial hydrolysis because it is water molecules that are being ionized by the gelatin. During this reaction, the plasticity of the solution also changes.

The solubility, stability, and plasticity of the protein compounds change[1] at temperatures greater than 100°C, which is why in order to set food like Jello, you must bring the water to a boil. However in this experimental case, there was no heat added and the powdered gelatin was used to create a layer of solution.

Typically gelatin has a density of about 1.3 to 1.4[1], while plain water remains as 1. I hypothesize that it is this difference in densities that causes a visually 'wrinkled' surface. Because this phenomena is not a current subject of research, I must clarify that all reasoning is a proposition of explanation and has not been proven. When the gelatin is sprinkled onto the water's surface, the chemical reaction begins, and the water begins taking on the protein polymers. In this process, the plasticity of the gelatin gives the new solution some 'body', a stronger layer of surface tension. At the same time, the solution is increasing in density without gaining mass, therefore the volume must be the property that changes. This mathematical balance of properties is shown in the equation below.

$$\rho = \frac{m}{V}$$

Where in the equation, ρ is density in units of kilograms per cubic meters, m is mass in kilograms, and V is volume in cubic meters. Without any numerical calculations, it can be observed that if mass cannot be created or destroyed within a system, a fundamental law of physics, and the density is increased, then the volume must be decreasing. Physically, what this equation is implying, is that the solution created in the pie dish must shrink.

This hypothesis is reinforced throughout multiple experiments as the chemical reaction evolved. As time progressed, the surface would continue changing for several minutes. Furthermore, there was a repeated 'waterline' of gelatin, which is assumed to be the volume at which the reaction started.

It would be due to this progressive reduction in volume that the increasingly tight surface tension buckled. This buckling to our eye is recognizable as a wrinkled surface, as I attempted to capture in Fig.1.

Experimental Setup

To get the desired results required a small ensemble of household items. The materials list and procedure for the image in Fig.1 is as below.

Materials

- Knox Kraft Gelatine Unflavored - 7g Packet
- Kroger® Assorted Food Coloring Kit
- Cold Tap Water
- Pie Dish - 10" Diameter
- White Curtain
- LED Lamp and Shade

Procedure

To begin, I placed the white curtain over a kitchen chair such that it draped flat onto the floor and extended several feet. This flat area was the experimental workspace and the drape off the chair served as a photographic background as shown in Fig.2. The lamp sat on the same chair, lighting the workspace from the back.

In the glassware, I directly added two drops of the orange food dye. Running my kitchen faucet until it was ice cold, I then added the cold tap water into the container until it was approximately 2 inches deep, or about a half inch away from the top lip of the dish. Any die that was unmixed by the addition of water was further distributed by stirring with my finger. The dyed water was then placed in the center of the workspace.

Quickly after, as to not gain too much heat in the water from the ambient room temperature, the photographic assistant in this experiment emptied an entire gelatin packet evenly across the colored water's surface. Immediately after this action, without any agitation to solution, is the moment of visual interest and the photographer must have the shot ready prior to the addition of gelatin. I repeated this procedure as many times as my stock of material permitted.

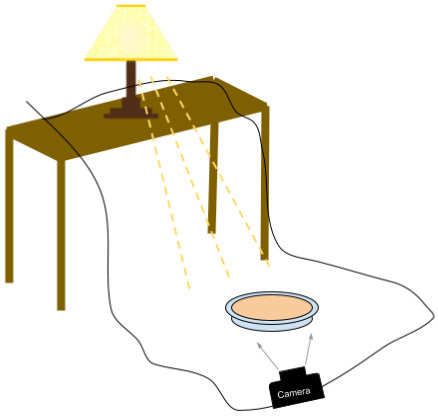

Figure 2: Representation of the experimental set up outlined in the procedure

Photographic Decisions

Apart from having no prior experience in flow visualization, I had little experience in macro photography. Reflecting on the techniques I employed for this picture, there is room for great improvement. To capture the flow I used a Nikon D3400 DSLR Camera with a 18-55mm Lens that I rented from the Norlin Multimedia Equipment Lending Library. The field of view just fits in the pie tray and a little of the background curtain. The camera was being held at about a 15 degree angle from the ground about 6-8 inches away from the container. Unfortunately, the camera was throwing a 'Press Shutter Button' error and could not be rectified. For these reasons the image was shot on auto settings which were not recorded.

In editing, I cropped the focus onto just the pie dish and brightened the image by using a non-quantitative slider in the apple preview editor. The before and after images are shown in Fig.3 where the unedited is on the left and the edited image is on the right. I made these choices because it better accentuates the flow phenomenon that is the wrinkly surface. In brightening the picture, I artistically wanted the reflection of backlight through the gelatin.

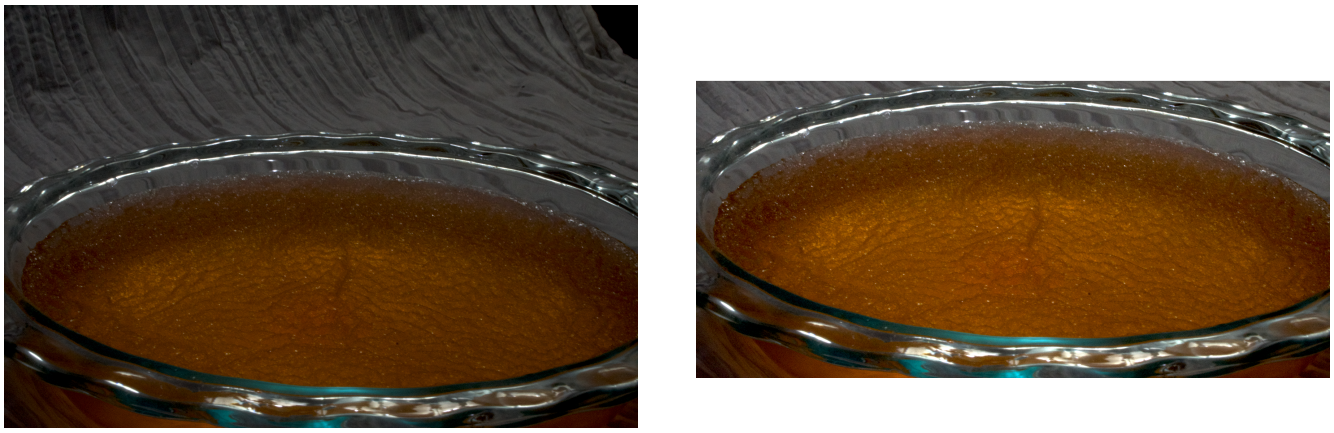

Figure 3: Shows how editing choices create differences in the original and submitted image. The left is the unedited image, and the right is the image that has been edited and submitted.

Conclusion

The image presented in Fig.1 was eye opening experience into the world of flow visualization, and more importantly, into photography. Learning from this experiment, I would have had more creative liberty, and a better representation of the physics at play, if I had used a macro lens and made my edits in Darktable. In the future, this picture made me excited for all the types of flow that are commonplace but hard to do justice to.

References

[1]Keenan, Thomas R. "Gelatin." *Kirk-Othmer Encyclopedia of Chemical Technology*, 2000, https://doi.org/10.1002/0471238961.0705120111050514.a01.