**Flow Visualization 4151-003: Get Wet**

**Quintin Smith**

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The first project in the Flow Visualization course aimed to capture a video of a sugary liqueur within a glass bottle. Titled "Liquor Physics", a bottle of blue shimmering vodka liqueur was used as a subject for the video with a bright white light swept around the circumference of the bottle to highlight different features of the flow. This exact product was chosen because of its addition of food-grade glitter (mica powder) within the liqueur. This made for stunning visuals and an excellent flow visualization as the bottle was shaken. In swirling the liquid to excite the glitter, there was a surprising effect from the viscosity of the liqueur that acted on the glitter, dramatically slowing the turbulent flow within seconds of shaking the bottle.

Shown below in Fig. (1) is the experimental setup with arrows indicating the flow around the bottle and a scale for reference.

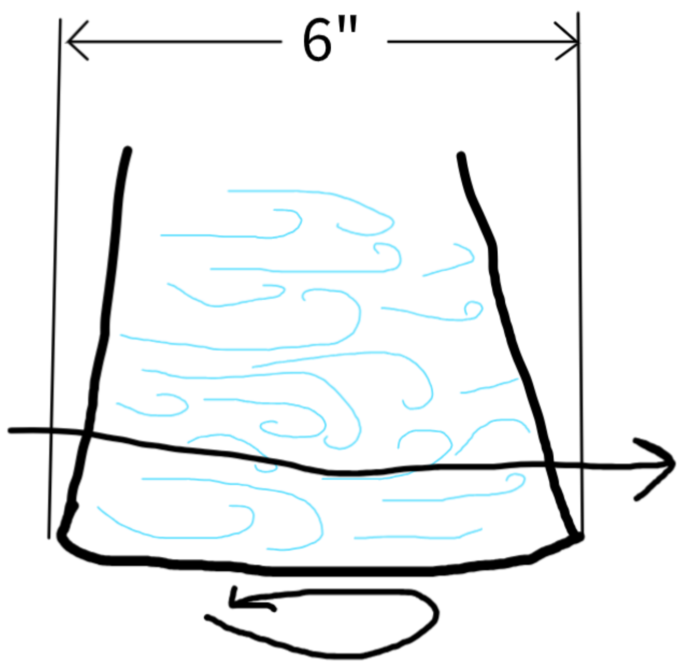


**Figure 1.** A sketch of the cylindrical bottle used for the Get Wet project. Top arrow indicates general flow behavior, bottom illustrates direction of swirling around the bottle (counterclockwise). Bottle diameter is 6 inches.

After initially swirling the bottle, the fluid would dramatically slow down and the somewhat chaotic flow would become noticeably less turbulent and would sometimes appear to transition to laminar flow if left alone. Though there are likely several reasons for this, the most outstanding are viscous forces and friction forces along the inner surface of the bottle. The liquid inside the bottle is noticeably more viscous than water. Since viscosity is a measure of a fluids resistance to flow, a greater viscosity means the fluid will naturally decrease its velocity more rapidly [1]. Given that the flow is not being exclusively interrupted by the walls of the bottle, the viscous forces appear to be the most prevalent. However, there is still a bit of frictional force along the walls of the bottle as the glitter's speed at the surface is slower than the fluid flow slightly further from the inner wall. Although, this is not extremely noticeable. Later in the recording, small mica particles can be seen moving perpendicular to the flow of the rest of the fluid. Most of the particles travel around the bottle's circumference through the entire process.

For the following Reynolds number calculations, the velocities within the bottle are an estimation of the mica powder's movement around the circumference of the bottle. Initially, the velocity was about 6 inches per second, or .152 m/s and slowed to around 1 inch per second or .025 m/s. To estimate viscosity, similar recipes for the drink were found online and it was found that there is about 53 grams of sugar per cup of liqueur. With this known concentration, it can be estimated that the absolute viscosity is about 6 cP or .006 newton second/square meter [3]. Also, this concentration has a density of about 1333 kg/m^3.

To find the Reynolds number with the initial speed of .152 m/s, the equation used was

$$Re = \frac{\rho U D}{\upsilon}$$

with $\rho$ being the liquid's density and $\upsilon$ being the liquid's absolute viscosity. A diameter D of 6 inches or .152 m was used. This came to

$$Re = \frac{1333 \cdot .152 \cdot .152}{.006} = 5{,}133.$$

In other words, significant enough to be considered fully turbulent. For the .025 m/s flow, it came to

$$Re = \frac{1333 \cdot .025 \cdot .152}{.006} = 844$$

which is much smaller can be considered fully laminar flow.

As previously mentioned, a glitter made of mica powder was used to visualize the movement of the fluid within the bottle [2]. This powder was standard with the bottle of Viniq Shimmering Vodka Liqueur and the experiment was done with no modifications to the subject. For lighting, a white iPhone flashlight was used and was panned around the outer circumference of the bottle to get the different lighting effects on the mica powder and different colors as the light passed through the fluid. The light started on the right side of the bottle, nearly touching the glass, to highlight the color of the liquor. It was then passed around the circumference a bit further away (very slowly) toward the direction of the camera to highlight the reflections of the mica. It then concluded at the opposite end of the bottle and was pointed toward the table for a dramatic "fade out" effect.

The camera was zoomed to a focal length of 55mm f/7.1. The field of view seen is just under 5 inches from the top of the frame to the bottom, as the bottle occupied the entire frame. The bottle was placed about 10 inches from the lens and was recorded using a Canon t6i at 1080p 30 fps, ISO 1600, 1/30 shutter speed, and a playback of 29.97 fps. The video was post-processed in Adobe After Effects with minor brightness and contrast adjustments and a color grading LUT with 20% opacity to enhance the blues and whites. At the final 5-10 seconds of the video, an effect called “Echo” was applied to stack 30 frames (1 second) of footage to create a particle trail. This was done to highlight the noticeable slower flow within the bottle.

At the very beginning of the video, the fluid in the bottle displays excellent turbulent flow. The calculated Reynold’s number of 5,133 confirms this behavior. As the video progresses, it is obvious that the movement of the mica powder (the glitter in the bottle) begins to slow and moves into the laminar range with a Reynold’s number of 844. The video is very aesthetically pleasing and highlights the travel of the fluid quite well. However, the initial turbulence is not easily seen as the light used was not placed at an ideal angle for seeing the initial chaos within the bottle. However, it can be seen very briefly at the start of the video after the text fades away.

Though the video was generally a success, I would have liked to have spun the bottle a bit faster to the chaotic movements can be visible for longer. This would have required some external force other than myself, as this is the fastest I could get the fluid to move by hand. The questions I have are about the accuracy of the Reynold’s number. Namely, if my assumptions for calculating the Reynold’s number are correct and if it’s possible to directly measure the speed of the flow around the glass for a more accurate Reynold’s number calculation. This leads to where I would develop this, and that is by improving the velocity calculations and directly finding the liqueur’s viscosity as the numbers I used were a rough estimate based on research of sugar water.

***References***


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[3] Pumps, G. (n.d.). List of Typical Viscosities. Www.globalpumps.com.au. https://www.globalpumps.com.au/list-of-typical-viscosities