Toy Car in the Rain

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MCEN 4151 Flow Visualization

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Figure 1: Blue died water being poured on top of a model Volkswagen Beetle

Introduction

This image was taken for the first team project in the Flow Visualization course. The intent of it was to visualize how fluids flow around an object as it moves through the fluid, however, due to limitations with the apparatus we instead visualized droplets of fluid around an object. I would like to thank Sam Nicastro for his help in the setup of the model, as well for lending his camera for this shot. I would also like to thank Cooper Lay for his help setting up the experiment.

Procedure

In this setup, I had a model Volkswagen Beetle elevated from the bottom of a bucket with acrylic stands. Behind the bucket was a curved, white photography background. I then poured water on top of while injecting blue food dye into the water to get as high concentration of dye as possible. As seen in Figure 2, water was poured from about a foot above the car model, which was about four inches long.

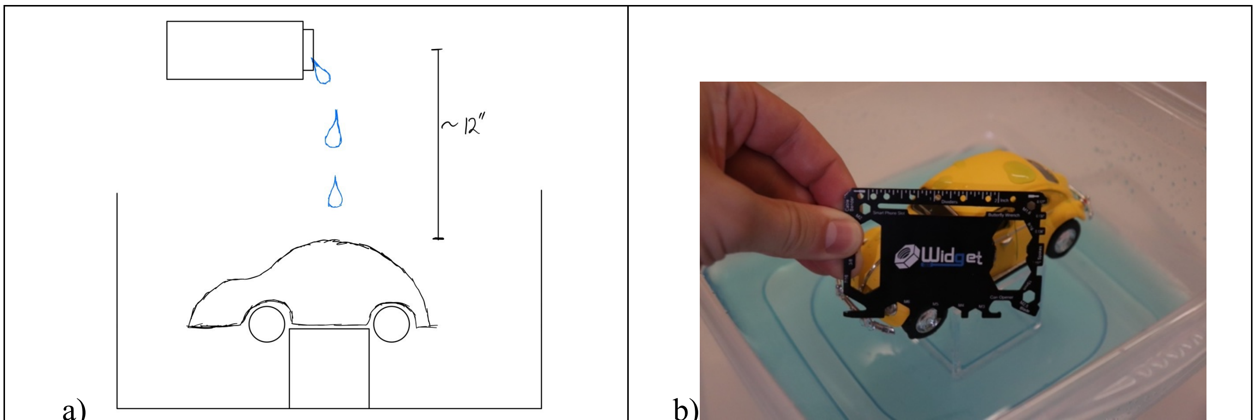

Figure 2: a) A drawn diagram of the vertical scale of the experiment.
b)A ruler next to the model car for scale.

The experiment was lit by room lighting, plus a phone flashlight and a 350-lumen headlamp with tissue paper in front of it for diffusion. These two lights were put on either side of the camera, about in parallel with the camera lens. The camera was placed about a foot and a half away from the subject with a 1/1000 exposer time, an aperture of 5.6, and ISO of 3200, and a focal length of 48 on a Canon ESO 77D. Color correction on the image consisted mostly of increasing brightness and saturation, and the original image can be seen in Figure 3. The image was not cropped and remains at 4,000 by 6,000 pixels.

Figure 3: The original, unedited image.

Discussion

The flow consisted of individual droplets hitting the roof of the model. One interesting note about the flow was how much the fluid remained attached to the surface rather than bouncing off instantly. This effect can be seen in Figure 4.

Figure 4: A ring of water engulfs the model car.

By using the scale of the model, it can be determined that the droplets are 0.25 inches wide. Additionally, using the conservation of energy (equation 1) .

$$mgh = \frac{1}{2} m{V_1}^2 \quad (1)$$

Regaining to solve for velocity and plugging in the values.

$$v = \sqrt{2gh} = \sqrt{2 \cdot 32.2[\frac{ft}{s^2}] \cdot 1[ft]} = 8.02\left[\frac{ft}{s}\right] = 5.47[mph] \tag{2}$$

After being poured from a height of one foot, I found that the droplets are hitting the roof at a speed of 5.47 *mph* under the following assumptions: air resistance is negligible, and the droplets had an initial vertical velocity of zero. Now, to find the Reynolds number (equation 3) of the flow across the roof of the model,

$$Re = \frac{V \cdot D}{\upsilon} \tag{3}$$

we can use the conservation of mass to get the velocity of the fluid on the roof. I assumed the thickness of the flow across the roof to be 1/32nd of an inch, as seen in Figure 5a), as it flows out in disc shape from the point of contact. Treating the droplet like a continuous jet hitting the surface during the time of impact, we can determine the velocity of the fluid on impact by setting the flow rates equal, as seen in Figure 5b).

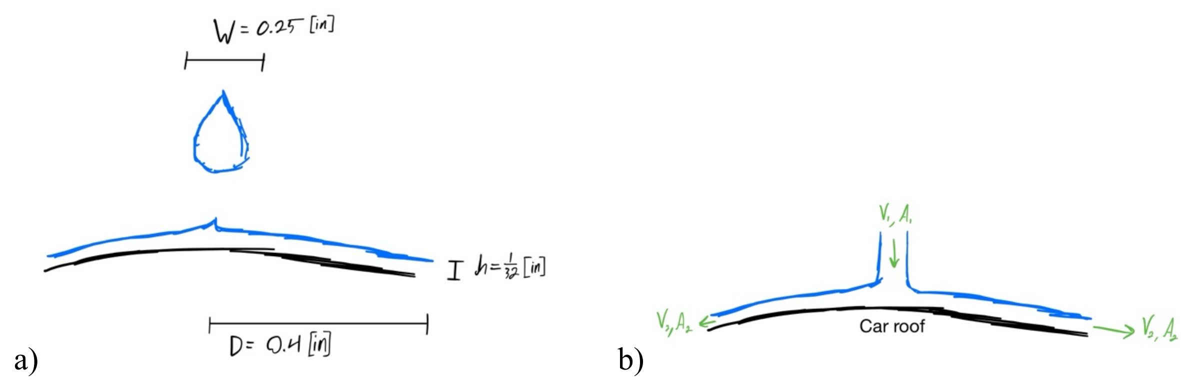

Figure 5: a) Dimensions used in calculations
b) Treating the droplet like a continuous jet for mass conservation

$$V_1 A_1 = V_2 A_2 \tag{4}$$

$$V_2 = \frac{V_1 A_1}{A_2} = \frac{V_1 \cdot \frac{1}{2}\pi \cdot (\frac{W}{2})^2}{\frac{1}{2}\pi \cdot w \cdot h} = \frac{96.24[\frac{in}{s}] \cdot \frac{1}{2} \cdot \pi \cdot (\frac{0.25[in]}{2})^2}{\frac{1}{2} \cdot \pi \cdot 0.25[in] \cdot \frac{1}{32}[in]} = 192.48\left[\frac{in}{s}\right] = 10.9[mph]$$

Then I plugged in the velocity of water on the model roof into the Reynolds number equation (3). I set the characteristic length to be the radius of the roof so that it would be analogous to external flow on a flat plate where the characteristic length is the length of the plate. Also, the kinematic viscosity of water at 60°F is $\upsilon = 0.00161899\left[\frac{in^2}{s}\right]$ [2].

$$Re = \frac{V \cdot D}{\upsilon} = \frac{192.48\left[\frac{in}{s}\right] \cdot 0.4[in]}{0.00161899\left[\frac{in^2}{s}\right]} = 47{,}536 \tag{3}$$

This would indicate that the flow across the roof would laminar when compared to the flow across a flat plate, where the critical Reynolds number is 500,000 [3]. I would agree with these calculations based on visual inspection of the flow.

Conclusion

This image reveals flow patterns around the model car. I really like the color that the food die added to the photo and how the drop is captured just before impact. I think that the flow physics is better shown in Figure 4, and I wish I could combine the flow in Figure 4 with the color of my final image. Still, I think that I could have done a better job demonstrating the flow physics, and it is something I would like to work on in the future. If I were to improve this experiment, I would like to have significantly more fluid flow with a few streams of dye inside of it, almost like a wind tunnel but with water.

Work Cited

[1] Momentum and forces from fluid in motion. (n.d.). Kdusling.github.io. https://kdusling.github.io/teaching/Applied-Fluids/Notes/Momentum

[2] Engineering ToolBox. (2004). *Water - Dynamic and Kinematic Viscosity*. Engineeringtoolbox.com. https://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html

[3] *Examining Reynolds Number for Laminar Flow*. (n.d.). Resources.system Analysis.cadence.com.https://resources.system-analysis.cadence.com/blog/msa2022-examining-reynolds-number-for-laminar-flow