Flow Visualization: Get Wet Report

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Bottled Fire

Fire can pose many dangerous hazards to people and structures, but when handled properly in a controlled environment, fire can produce one of the most interesting phenomena in the world. This is why capturing images of fire can be so extraordinary and dramatic. Passage of fire through enclosed spaces can also produce a spectacular image; the foundation for recording my Get Wet image. Spraying a lighter or match with a flammable fluid is a phenomenon that is commonly seen where the flammable fluid ignites when it hits the flame and creates a plume of fire. To capture something more interesting, I channeled the flame into a glass bottle to see what type of combustion imagery would result.

To set up such an experiment to photograph a flame traveling through a glass bottle, I first took precautionary measures to ensure everyone's safety who was involved by closely following The Combustion Experiment Guidelines. The experiment took three people to execute; one person (Jacob Engelman) held the glass bottle with leather gloves for protection, I operated the spray bottle (a can of WD-40) and the match, and the third person (Marisa Rael) photographed the image a safe distance away. The person operating the spray bottle triggered the spray with a 3 foot metal pole and held the match with wrought iron fireplace tongs.

After all safety precautions were taken, the experiment and photography commenced. As seen in Figure 1, a lit match was held with fireplace tongs before a 12-ounce glass bottle that was open on both ends so that the flames could travel in the bottom of the bottle and out the bottleneck. The WD-40 was then triggered, forcing a plume of ignited WD-40 particles through the bottle and out the bottleneck. Meanwhile, the photographer stood nearby to capture the image. In this way, the flame was forced to travel through the bottle in a dramatic fashion. As the spray from the WD-40 comes in contact with the fire on the match, the spray ignites. The force from the spray of the moving WD-40 particles powers the flame to move in the bottom of the bottle and out the bottleneck. Once the flame is out of the bottleneck, its heat forces it to rise due to convective heat transfer. Finally, the flame is extinguished when I stop spraying the WD-40 because there is no more fuel to ignite.

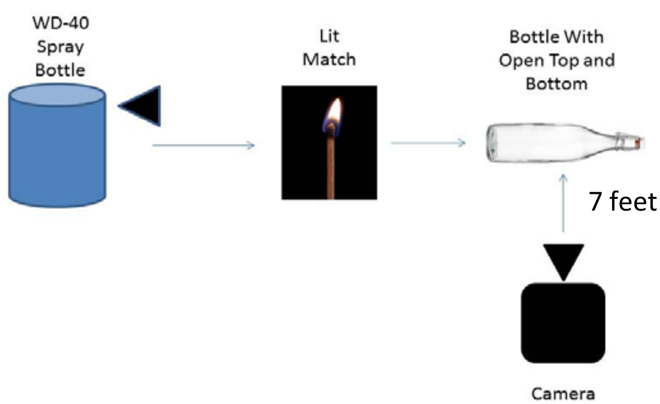

Figure 1: Flowchart of Experimental Setup

By looking up the Materials Safety Data Sheet on WD-40 , the kinematic viscosity is determined to be $2.875 * 10^{-6}(\frac{m^2}{s})$ [1]. The velocity of the moving fluid can be calculated by measuring the horizontal distance the flame traveled and dividing by the time it took to travel that distance. The flame travels about 2 feet (0.61 meters) in about 0.25 seconds, which is 8 feet per second (2.4 meters per second). Therefore, the Reynolds Number calculation is shown in Equation (1). Since the Reynolds Number is very high (much greater than 4000) the flow can be considered turbulent [2].

$$Re = \frac{UD}{v} = \frac{2.4\left(\frac{m}{s}\right)*0.61(m)}{2.875*10^{-6}\left(\frac{m^2}{s}\right)} = 510000 \qquad (1)$$

Figure 2: Original Image

The main visualization in the image is fire as seen in Figure 2 in the original image. The bottle adds an artful enclosure to the flames, but the fire is the primary visualization technique. Having all the necessary common household items to perform and photograph this experiment made it cheap and reproducible. To highlight the flame in the photograph, the image was taken in a dark corner of a parking lot on a night where there was not a lot of wind. I did not use the flash on my camera; rather, I let the light from the fire illuminate the scene in the image.

When photographing the image, the photographer, Marisa Rael, stood about 7 feet from the glass bottle and flame. The picture was taken with a Samsung ST65, which is a standard point-and-shoot digital camera. A shutter speed of one second was used to try to capture the flow of the flame as it traveled through the glass bottle. When capturing the image, an ISO speed of 200 was used in combination with a lens focal length of 5 mm, an aperture of 3.61, a field of view of 9.6 feet by 7.2 feet, and an F-stop of f/3.5. The original image is 4224 by 2816 pixels, and the final cropped and edited image is 1062 by 829 pixels measured width by height respectively. To edit the photograph, the image was cropped in Adobe Photoshop. The only other edit came from altering the curves adjustment tool in Photoshop to better see the glass bottle and sharpen the lines defining the flame. The edited image can be seen in Figure 3.

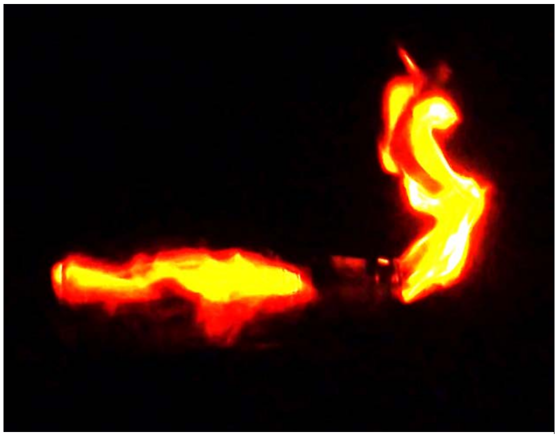

Figure 3: Edited Image

Capturing this phenomenon reveals a number of aspects of combustion. First, it proves how flammable WD-40 is. Also, it shows how the force from the spray of the WD-40 can produce a chain reaction that can carry a flame a sizable distance away from the spray bottle. Overall, I am satisfied with how the final image looks. When performing the multiple iterations of the experiment, I captured many images that showed a large flame engulfing the glass bottle. On the instance that I chose as my final image, the entire flame traveled through the bottle and revealed a dragon-like visual as the flames rose out of the bottleneck. However, as many critiques conveyed, the image is slightly blurry, which is most likely due to a long shutter speed producing a lack of focus in the camera since the setting was very dark. In the future, I would repeat the experiment with soft lighting in the background. This would help to illuminate the bottle and to let the camera focus on the bottle while still highlighting the flames. I would also reduce the shutter speed used on the camera to sharpen the details of the flames. In the future, a high-speed camera may be used to capture the entire phenomenon of the WD-40 igniting and the flames traveling through the bottle and out the bottleneck as it is a spectacular phenomenon in its entirety.

References

[1] “WD-40 Company - MSDS Sheets for WD-40, Spot Shot, 2000 Flushes, X-14, 3-IN-ONE, Carpet Fresh, Lava,” Web. 11 Feb. 2013.

[2] Young, Donald F. *A Brief Introduction to Fluid Mechanics*. 4th ed. Hoboken, NJ: Wiley, 2007. Print.