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Team First Report

Introduction

The purpose of the team first project was to collaborate with a team and find a fluid flow that was interesting to the group while still having artistic value. The intent of this image was to create a “Whoosh Bottle” and to photograph the combustion reaction that took place for the project. A whoosh bottle is a general term that describes a setup where, usually, isopropyl alcohol is added to a glass bottle and allowed to partially evaporate. Once the alcohol is partially evaporated a flame is introduced at the mouth of the bottle which causes the alcohol vapors to ignite. As the alcohol vapors burn there is an audible “whooshing” noise as the combustion forces air out of the mouth of the bottle. For this project I worked with Lara Buri, Madison Emmett, Cara Medd, and Michael Guenther. At first, we didn’t let the bottle sit in the sun long enough so there was not enough vapor and then liquid alcohol just burned slowly. Once we figured out that we had to let the bottle sit in the sun for approximately fifteen minutes we were able to perform the experiment with recurring success.

Experimental Setup

The flow apparatus that we used was a simple one-gallon glass jug that was filled with approximately 40-50 ml of 91% isopropyl alcohol. As discussed above the jug was then placed in direct sunlight for approximately fifteen minutes to facilitate the evaporation of the alcohol. Once the bottle had sat in the sun for long enough we then brought it to the table that we had set up with a black tablecloth and black background. Below is a picture of the setup that we used to capture all our images. The camera was positioned on the tripod in a portrait orientation so that we could zoom in on the bottle but still capture the whole bottle and the flame.

Figure 1: Experimental Setup

Flow Physics

The flow that is seen in the original picture is an example of a combustion reaction taking place within the glass jug. Once the isopropyl alcohol has partially vaporized and the alcohol molecules have spread out within the jug the flame is introduced. When the flame is introduced the combustion reaction starts, and due to the increased surface area, the combustions reaction occurs very quickly [1]. By using a video we took of the combustion reaction and the height of the jug, we can calculate the speed at which the flame moves through the jug.

$$v = \frac{\Delta d}{\Delta t}$$

Using the above equation coupled with the height of the jug (Δd = 11.5 in.) and the elapsed time of the reaction (Δt = 2 sec.). Using these values we find that the velocity of the flow is 5.75 in/s. Using this velocity we can then calculate the Reynolds number to determine if the flow is laminar or turbulent. In the equation for the Reynolds number we need three pieces of information the fluid velocity, the diameter of the jug, and then kinematic viscosity.

$$Re = \frac{vD}{\vartheta}$$

Using the velocity that we found above, v = 5.75 in/s (0.146 m/s), the diameter of the jug D = 6.6 in. (0.168 m), and the kinematic viscosity of atmospheric air at room temperature $\vartheta = 1.52x10^{-5}\frac{m^2}{s}$ we find that the Reynolds number is Re = 1613.68. This Reynolds number is says that the flow should be laminar but we see from the picture that it is turbulent. From this we can assume that there are other forces at play that are causing the flow to act the way that we observe it. The combustion reaction is caused by the alcohol and then oxygen in the air being combusted and turned into carbon dioxide and water vapor.

Image

The final image was obtained during one combustion reaction. The photo was taken with a Canon EOS 5D Mark II camera with a 28-75 mm, 1:2.8 lens. The shutter speed was 1/80 sec. the f-number was f/2.8, and then ISO speed was ISO-1000. The camera was placed between roughly 2-3 ft. away from the jug. The field of view of the image was approximately 7 in. so that we could capture the entire jug. When the combustion reaction was started we did our best to block out all the light besides the light provided from the combustion reaction. I decided not to do any post-processing on this image because I liked the color as it was, and I also like how the flame looked to be floating in the middle of the frame. Below is the original/final image.

Figure 2: Original/Final image

Conclusion

The image turned out to be very interesting and entrancing. As stated earlier I liked how the flame seemed to be floating in mid air and this was made more apparent by having the camera oriented in the portrait direction when taking pictures. I also liked how it sort of looked like a cloud as the flame as it moved up through the jug. I think that the physics of the flow are shown well, and the snapshot of a combustion reaction is a very interesting flow phenomena. Moving forward I would like to try to combust different liquids and materials to try and get different colored flames.

References

[1] https://www.flinnsci.com/api/library/Download/bf2f0d16dd86411ea26eb0cb687dc593