MCEN 4151- Flow Visualization

Team Third Report

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Section 001
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I. OVERVIEW

This video was shot for the Team 3rd Assignment for MCEN 4151- Flow Visualization. I started out trying to capture the smoke the rises when a match burns out. I first tried lighting a match inside of a jar and then closing the lid, so that the match would consume all the oxygen and burn itself out. However, the glass of the jar made it complicated to capture a clear image. When lighting matches within a jar, I realized that there is a lot of activity when lighting one match with another, so I pivoted to capturing this interaction instead.

II. EXPERIMENTAL SET UP

The video was shot on an iPhone 11 pro. I started out shooting with a Sony a7II camera, but it didn't work very well in given the conditions when I was shooting. I chose to shoot outside in the snow as a safety precaution since I was working with fire. I was working at night in order to most clearly capture the flame, but I couldn't quite get the flash right against the snowy background with the digital camera.

In order to keep the match in place, I poked a hole in the lid of a jar. I then placed the lid in the snow on a table in my back yard. I was placed a BioLite AlpenGlow 500 Lantern just outside of the frame to help the camera focus.

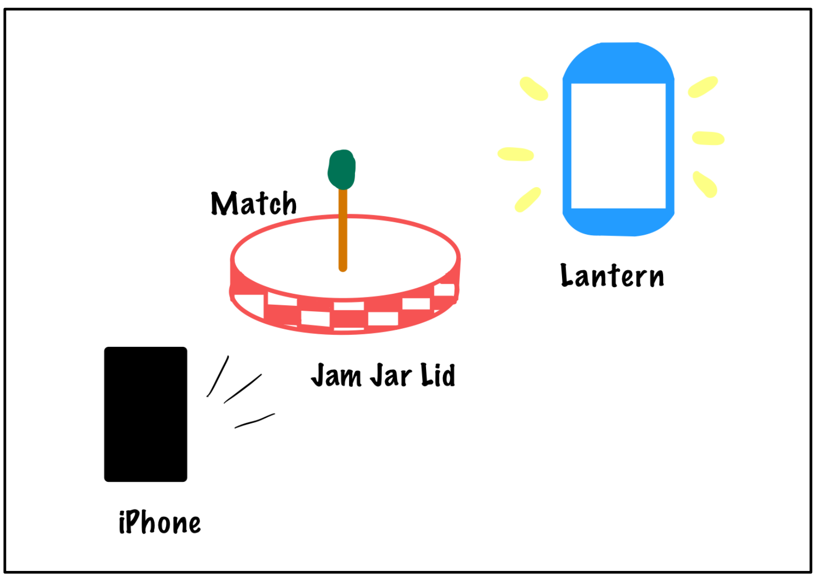

Figure 1.
Experimental Set- up

III. FLUID DYNAMICS

The motion of the smoke through the air can be described using The Navier- Stokes equations. These equations relate the pressure, density, and temperature of a moving fluid [1]. These equations are shown below [2].

(x direction)

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial p}{\partial x} + \rho g_x + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

(y direction)

$$\rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) = -\frac{\partial p}{\partial y} + \rho g_y + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right)$$

(z direction)

$$\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial p}{\partial z} + \rho g_z + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)$$

Due to their complexity, The Navier- Stokes equations cannot be solved analytically. Instead, it is necessary to use Computational Fluid Dynamics (CFD). These equations include time-dependent continuity equations for conservation of mass, energy, and momentum. The momentum equations include convection and diffusion terms [1]. Convective gas flow is caused by the motion of particles while diffusive gas flow is driven by the fluid viscosity, turbulence, and boundary layer motion [1].

IV. PHOTOGRAPHIC AND VISUALIZATION TECHNIQUES

The field of view of the original video was larger than it needed to be, so I ended up cropping the video during post- processing. During post- processing I also increased the warmth and vibrance to really bring out the color of the flame.

Table 1.

Camera	iPhone 11 Pro
Focal Length	NA
F- Stop	NA
Aperture	NA
Shutter Speed	26.83 fps
ISO	NA

V. CONCLUSION

This video fell short of what I was hoping to achieve. It was interesting to watch the match ignite, and the smoke disperse in person, and I don't think the camera was quite able to capture this. If I were to do this again, I might want to try it inside where light could be controlled better. Alternatively, I might try shooting against a darker background since the snow caused some funky reflections. Additionally, I think it would be worth trying to work with a different camera, perhaps with a macro lens to capture the texture of the match. While this specific instance was disappointing, it has made me want to pursue capturing a similar image in the future.

VI. RERERENCES

[1] "Navier-Stokes Equations." *NASA*, NASA, www.grc.nasa.gov/www/k-12/airplane/nseqs.html. Accessed 6 Dec. 2023.

[2] Munson, Bruce Roy. *Fundamentals of Fluid Mechanics*. John Wiley & Sons, Inc., 2014.