Group Project 1:
Fire propagation

By
Molly Selting
HwaPyong Ko
Christopher Skallerud
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Flow Visualization

The Image

The purpose of this assignment is to observe, photograph, and understand the fluid dynamics and phenomena in fire. The experiment was conducted in a garage in order to help control the surroundings. We began attempting to capture the phenomenon of flame propagation. To do this we used rubbing alcohol (isopropyl) because it propagates the flame slowly. We tried many different set ups with different geometry and alcohol amounts. The garage provided a perfectly dark area to allow only the flames light to be captured in the image. The garage also protects the experiment from outside wind and rain. In the end we chose an image that captured the flame quickly propagating across a paper plate because of the interesting physics demonstrated.

Flow Apparatus

In order to capture a good image of the fire, we needed to come up with an apparatus that allowed us to see the flame with out being to close. The apparatus we chose is shown in figure 1. A paper plate was placed on the floor under a ladder. A thin layer of rubbing alcohol was poured onto the paper plate and rubbed in. A black metal pizza pan was placed under the paper plate to keep the fire from spreading as well as to create a black background.

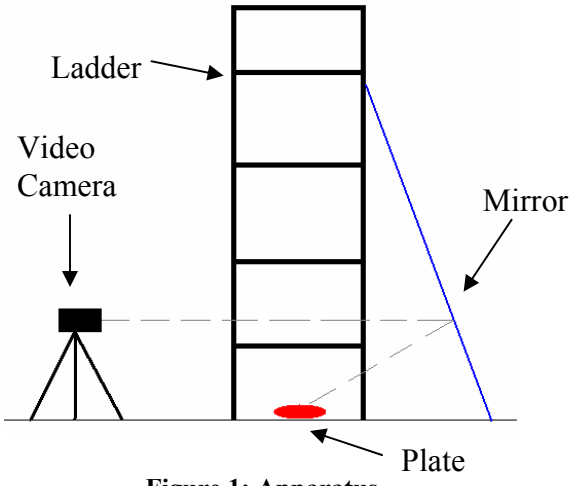

Figure 1: Apparatus

Due to the heat from the fire, the camera was placed perpendicular to the flame a safe distance away. The camera then captured the image off of a mirror that rested at an angle on the ladder that allowed us to view the flame. The total distance from the lens to the flame was approximately 1.2 meters.

Visualization Technique and Flow Description

To visualize the fire we chose to use rubbing (isopropyl) alcohol due to it's slow burning properties. The specific visualization we were interested in was the fire itself so since this viewing fire requires a good concentrated light only from the source, we worked in a completely dark garage. The only light present was the fire. Along with the black metal pizza pan we used white sheets of papers below it to help visualize the flame with contrast. It ended up that our plate was enough white to provide contrast.

The cause of the Propagation effect shown in this clip is due to the mixing of two different effects. First is Stoichiometry and second is diffusion. First the rubbing alcohol causes the plate to catch. Next the localized fire begins to propagate across the plate, along the stoichiometric path between the air and alcohol. The stoichiometric path is where the fuel is neither lean nor rich. The fuel and oxidizer mix and produce only water and carbon dioxide. If a mixture is lean there will be extra oxidizer left and if it is rich there will be extra fuel. After the flame begins to propagate the plate does not remain lit. This is due to quenching, it is a result of the rubbing alcohol consisting so highly of water and as the alcohol burns off the water quenches the flame. The flame then propagates across the plate again due to the alcohol diffusing up through the plate and coming to the surface and then igniting on the existing flame that is located on the edge of the plate. This happens multiple times until the alcohol is no longer strong enough to diffuse up through the plate. There is evidence of this in the spacing between each pass of the flame. This is due to the alcohol taking more time to diffuse through the plate due to its strength weakening because of the depletion of the fuel.

Photographic Technique

We took the image with digital video camera. Below lists show the specification of the digital video camera.

Type of camera: Sony Handycam Digital Video Camera – 0.68 Megapixel (320x240 pixels)
Frames per second (shutter speed): 1/730 sec.
Distance from object to lens: 36 in
Focus – Auto focus

The field of view is about 8 ~ 10 inches wide. The camera was set to auto management while the image was being recorded.

Analysis of Image

We are very happy with our final phenomenon captured. We worked backwards and captured the image first and then discovered the physics behind it. This afforded us a great learning opportunity. This image demonstrates a phenomenon that we didn't realize existed. Hopefully, through our image we can demonstrate this phenomenon to others who have not seen it before. We also feel that the physics captured in this image are not intuitive and we found it very interesting to discover why this phenomenon occurs.

If we were to perform this experiment again we would improve our image by using a camera with a better resolution and by using a sturdier tripod. This would add clarity to the image and thus help convey the phenomenon captured more completely.