Porous smoke - Get Wet, Vis Assignment 1

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INTRODUCTION

This was the first image taken for the flow visualization course and aimed to capture the laminar flow of burning incense through a porous surface. I was initially attempting to capture vortex streams through the individual holes on the porous surface but found the laminar flow and the collection of the incense smoke on the top of the surface to be more beautiful and intriguing. The porous surface, in this case, was an incense coffin.

APPARATUS SETUP

An incense coffin is a type of incense holder. It is a wooden box with several holes to release the incense smoke. This specific coffin has 12 holes on the top lid of the coffin, and 9 on one of the sides. The holes have a diameter of 0.5-1 cm. The incense, once lit, fits into a small hole inside the coffin on the narrow wall. The hole is slightly larger than the stem of a standard incense stick, about 0.1 cm in diameter. Figure 2 shows how incense is held within the coffin. Once the lid is closed, incense smoke can escape through the 21 holes in the coffin and through the lid opening. However, smoke typically rises out of the holes where the smoke is most concentrated. A diagram of the coffin can be found below in figure 1.

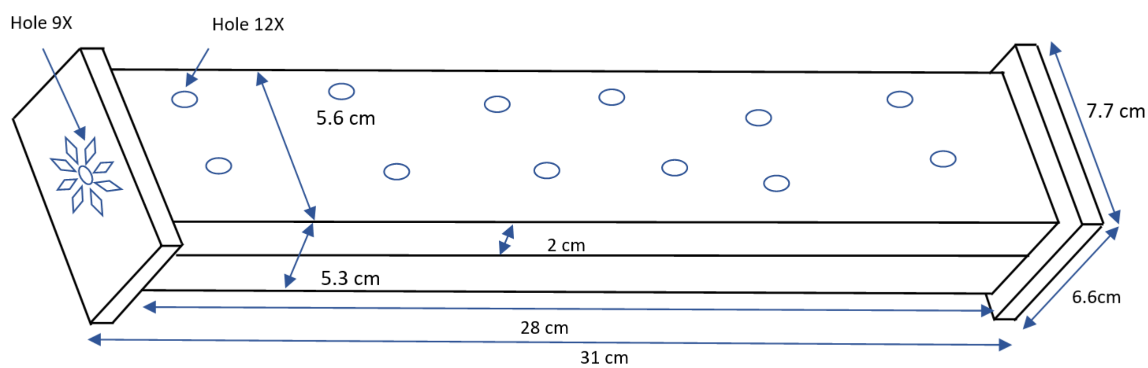

Figure 1: Diagram of incense coffin

Figure 2: Inside of the coffin with incense held inside

FLOW PHENOMENON

In this image, incense is encased in a wood coffin. As the incense burns, buoyant forces cause the smoke to rise because the incense smoke, made of chemicals such as CO_2, CO, SO_2, and NO_2 (1), is less dense than the cooler room temperature air around it (2). However, because the smoke is initially enclosed, it hits the sides of the wooden box, fills the space around the incense tip, and escapes through the top holes and the coffin opening. As such, the pressure of the smoke would increase as it moves through the holes. However, an interesting phenomenon occurs where instead of the smoke rising straight up through the holes in separate streams, it gathers back on the surface of the wooden coffin before rising in a single stream. The smoke in this situation is likely behaving non ideally and is affected by attractive forces. While in most instances, the kinetic motion of a gas renders the attractive forces almost negligible, in this scenario, the increase in pressure from the smoke moving through the holes at a relatively slow speed might cause the gas to behave non-ideally, making the attractive forces more significant (3). After gathering, the smoke begins to rise again due to the buoyant instability, as mentioned previously. This flow is laminar, meaning it will have a Reynolds number of less than 2000. Reynolds number is denoted by the equation

$$Re = \frac{VD}{\nu},$$

where V is the flow velocity, D is the diameter, and ν is the kinematic viscosity. For this approximation we can assume that the diameter is around 0.58 cm. Additionally, if we assume that the smoke composition is primarily carbon dioxide with a temp of 300 K then the kinematic viscosity of the fluid is $8.47 * 10^{-6} \frac{m^2}{s}$ (4) . If the Reynolds number is less than 2000 than

$$V \leq \frac{2000 * 8.47 * 10^{-6} \frac{m^2}{s}}{0.0058m}.$$

The velocity must be less than $2.92 \frac{m}{s}$.

IMAGING TECHNIQUES

This image was taken in a common bedroom with typical bedroom conditions, meaning that the room was between 20 and 25° C, with minimal convectional flow through the room. Both the incense and the incense coffin used were bought from small vendors at the Colorado Renaissance Festival in Larkspur Colorado. The incense was hand-dipped incense acquired from Two Sents Worth Oil and Incense, costing $3 for 12 incense sticks. The incense coffin was handmade from the vendor Kamala's Own for $15. I used two white sheets of printer paper for the background. The light used to take this image was a Rechargeable 96 LED Light, bought from Amazon for $22.95. The light's power was 9 watts, the color temperature was 5500K, and was placed at an angle of about 120° from the right. There was minimal other light in the room, no other lights were on, and blinds covered the only window in the room. A diagram of the camera and lighting position can be seen in figure 3 below.

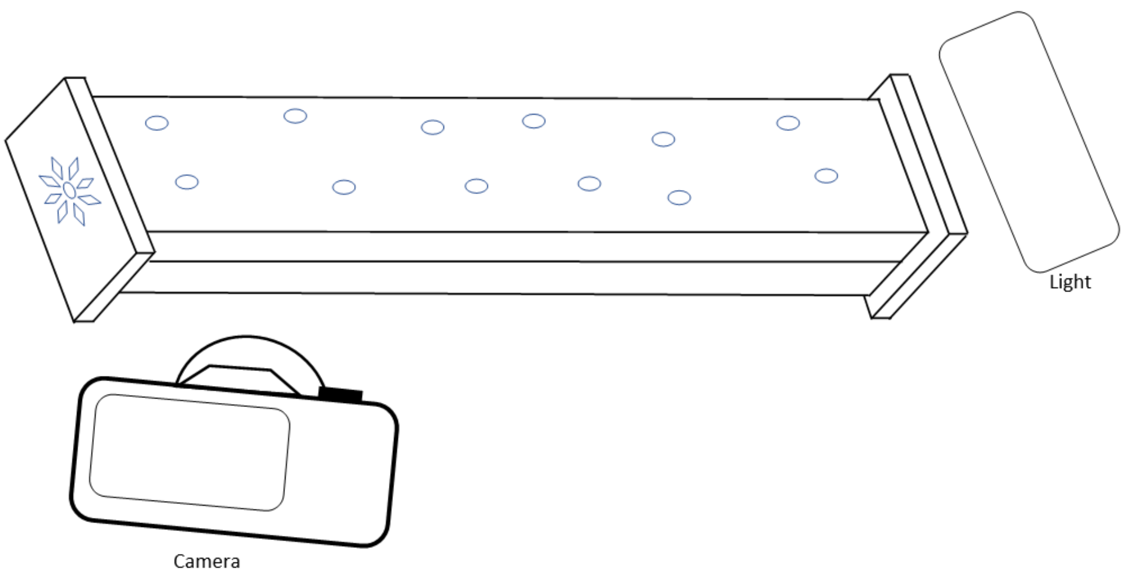

Figure 3: Diagram of experimental setup including camera and lighting position

A Canon EOS Rebel T7i camera with an 18-55 mm lens was used to take this image. The edited image has a field of view of about 9 cm wide and a focal distance of 25 cm. The camera specs were set to a focal length of 55mm, an ISO of 1600, an aperture of f/32.0, and an exposure of 1/160. I chose these settings because the light was close to the subject, and I wanted to keep the smoke illuminated and make the background as dark as possible. Additionally, I used a 55mm focal distance because that length created a close and more in-focus image than the other focal lengths available to me. The image was edited in Darktable. I cropped the image and added an S-curve to the rbg curve. The original image and the edited image can be seen below in figure 4.

Original: 6024 X 4020 pixels

Edited: 3952 X 3383 pixels

Figure 4: The original image and the edited image, image size is displayed underneath each in pixels.

I love the flow of this image; it is beautiful and captures the laminar flow of incense smoke through a porous surface well. I love how detailed the image is from the smoke to the wood grain. In the future, I would try to keep the light out of the original photo so that I have more options for cropping. Additionally, I want to take this image vertically to capture more of the upward flow.

Bibliography

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