MCEN 4151: FLOW VISUALIZATION

Smoke Rising in Air

Get Wet Image

Emily Howard

2/16/2012

The first assignment for the Flow Visualization course is the “Get Wet” assignment. For this assignment, each student is expected to take a photo of a fluids phenomenon that both demonstrates the situation and is artistically sound. The intent for my photo was to capture the transition of smoke as it rises from laminar flow to turbulent flow.

To create my smoke photo, I used trick (re-light) candles, play-doh, bedside table lamp, and a large piece of black felt. The set up can be seen in Figure 1 below. The black felt was attached to the back wall to provide a seamless and simple background for the photo. The play-doh was formed into a cylindrical shape and was used to keep the candles in place and allowed for the candles to switch out easily. Four candles were placed approximately one inch apart to show the variation in the different smoke trails. Trick candles were used as these were slightly taller than the regular birthday candles and because they produced more smoke. These candles were approximately three inches tall. The scene was backlit using a traditional table lamp, which was placed lower than the candles so that the light would not travel directly into the camera and produce flare in the photos.

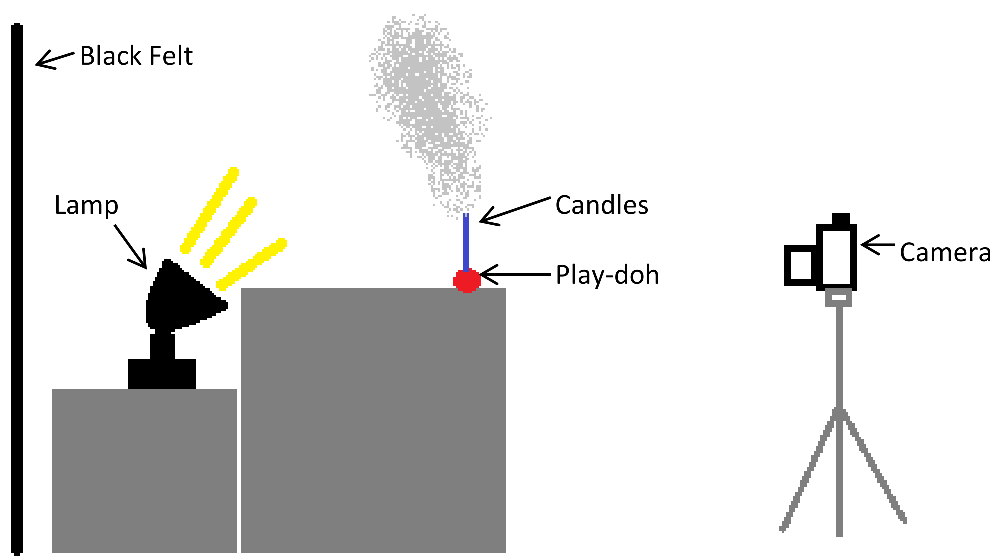

Figure 1: Side View of Photo Set-Up

The smoke rises because it is warmer than the surrounding air, and warmer air rises. This is due to buoyant forces of a warmer less dense fluid in a cooler denser fluid. The upward force carries the smoke through the air.

The flow in this image is the smoke traveling upwards from the candles. This shows the transition which the smoke goes through as the flow becomes less laminar, or smooth, to more turbulent, or chaotic. The flow in this picture never reaches a full turbulence, but ends at the top in the picture in the transition zone, or at a state in between laminar and turbulent flow. This can be seen in the patterns of the smoke in the top half of the frame. If the flow had reached the turbulent flow range, the smoke would seem more chaotic and would contain less of a pattern. These flows can be quantified by their Reynolds number, which is shown in Equation 1, ρ is the density of the fluid, V is the velocity, L is the characteristic length, and μ is the dynamic viscosity.

$$Re = \frac{\rho V L}{\mu} \quad \text{[Eq 1]}$$

It has been found that flow is laminar at a Reynolds number between 0 and 2000, and is in the transient between 2000 and 4000, and turbulent above this number[1]. The air pressure can be found according to the location of the shot, which was Boulder, CO, which leads to a density of approximately 1.1 kg/m^3[2]. The dynamic viscosity is a property of the fluid, and as viscosity of the smoke can be approximated as air, the viscosity of the fluid is 2.06×10^{-6} Pa-s[3]. The final value which can be found is the critical length. In this situation, the critical length is the distance the smoke has traveled from the camera. Using the picture and the reference of the 3 inch candles, the critical distance is estimated to be 4 inches or 0.102 meters when the smoke becomes transient. From this information, the velocity can be found at the point at which the smoke becomes transient, which is shown in Equation 2.

$$V = \frac{Re * \mu}{\rho L} = \frac{2000 * 2.06x10^{-5} Pa{-}s}{1.1 kg/m\hat{}3 * 0.102 m} = 0.367\frac{m}{s} = 1.2\ \frac{ft}{s} \quad \text{[Eq 2]}$$

The calculation shown in Equation 2 shows that the smoke does not reach a very high velocity before becoming transient.

This picture is spatially resolved, which can be seen by comparing the magnitude of the flow to the magnitude of the photo. The smallest point of interest in the photo is the flame. This is estimated to be around 1/8th inch. The largest part of the flow is all that is included in the frame. This is estimated to be approximately 20 inches. Comparing these two figures, there is a separation of 2 decades. The picture is approximately 2500 pixels in size, which is equivalent to 3 decades. As the flow requires 2 decades to be spatially resolved, and the picture has 3 decades of information, the photo is spatially resolved. This means that all parts of the photo impertinent to understanding the flow in the picture can be seen.

The visualization technique used here is the smoke, which is backlit, which highlights the particles in the air and makes the smoke stand out. The light was lower than the candles but angled up into the smoke to make it clear and more obvious. The light was also placed lower and behind the candles to stop the light from shining directly into the camera and creating flare.

The camera settings were carefully chosen to keep the smoke clear and in focus, but without keeping the background in focus. This required a short shutter speed, a low ISO, and a mid-level depth of field. The camera specifications and settings are shown in Table 1.

Table 1: Camera Specs and Settings

Camera Body	Canon Rebel T2i
Camera Lens	50mm
Aperture	1.8

Shutter Speed	1/125
ISO	400

The photo was digitally altered in Photoshop. The photo was cropped to bring the focus to the smoke. It was also brightened and the contrast was increased so that more detail could be seen the smoke. Finally, the photo was converted to black and white, as the color did not add any depth to the photo. The initial pixel size of the photo was 5184 x 3456, and the final pixel size of the photo after cropping is 3858 x 3186.

I feel that this image captures the beauty and fluidity of the smoke. The pattern that was captured is interesting and unique. If I were to retake these photos, I would try using a brighter light source, and a lower ISO to try to decrease the amount of grain in the photo. I would also try to move the camera closer to the scene so that I would not have to crop away as much negative space. To develop this idea further, I feel that the smoke could be captured at its different stages, or even videotaped.

References

[1]"Overview of Fluid Mechanics Theory." *EFunda.com*. EFunda, Inc, 2012. Web. 16 Feb. 2012. <http://www.efunda.com/formulae/fluids/overview.cfm>.

[2] Wolfram Alpha. "Density at 5000 Feet." Wolfram. Web. 15 Feb. 2012.

[3]The Engineering Toolbox. "Air - Absolute and Kinematic Viscosity." Web. 15 Feb. 2012.