Blooming Smoke

Group Assignment #2 Report

MCEN 4151 – Flow Visualization

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Group 7

Introduction

For the second group assignment in Flow Visualization, my group and I decided to work, primarily, apart but under the same basic idea. We had the desired to visualize the fluid flow of smoke so that we could compare visualization techniques and overall results. I had been searching for ideas and found the work of Graham Jeffery at his website (Jefferey). I was amazed by the beauty and detail of the fluid flows showing the basic air-flow around us all the time. It's amazing to see how much beauty we cannot see in the ambient air around us. On the website shown, Graham Jeffery not only shows many of his best images, but also gives many tips and techniques for capturing these images. In most cases, he uses incense smoke and it was with these basic tools that I worked with in order to capture my image (Figure 1).

Figure 1: Final image of incense smoke

Laminar to Turbulent Flow

The prominent fluid flow represented by this image is the transition from laminar to turbulent flow. The incense smoke was not affected in any way other than ambient air. In other words, I was not disturbing the fluid flow with fans or by moving the incense stick in any way. As seen in the image, the flow starts as a smooth diagonal line as the smoke rises directly from the end of the burning incense. Such flow requires that the viscous forces be larger than the inertia forces (Kothandaraman, Rudramoorthy). However, because the air which is entrained with smoke particles is hotter than the ambient air, it rises. The force which is responsible for this upward response is buoyancy. The hotter air is less dense than the cooler, creating a pressure difference which drives the air upward. At a point, the inertial forces begin to increase and become higher than the viscous forces which causes mixing of the fluid. This transition is seen very well in this image as the rising smoke transitions from laminar to turbulent flow.

In conjunction to this transition, we are able to see several very interesting spirals in the flow. As the spirals are very layered and easy to see, there is little mixing and the boundary layer has not yet

dispersed. This layering effect shows that the flow is not completely turbulent, however it is still mixing. Many of these spirals have three or even four complete rotations which occur very quickly. These spirals are known as vortex flow and are created by cross flow interaction. These cross flows create pressure differences which force the fluid to flow in a spiral motion with the minimum pressure at the center ("Vortex").

Visualization Technique

The technique used to visualize the interesting flows discussed previously is known as the seeded boundary technique (Hertzberg). The hot air from the burning incense is seeded with smoke particles which are able to scatter the light very effectively. The seeding is so dense that you are not able to see the individual particles, yet this high density also affects the fluid flow in general. It's important to know the effects of such techniques in order to better understand the physics involved in the fluid flow being captured. In this case the dense seeding caused by particles that are relatively dense themselves create momentum interactions that affect the fluid flow. Regardless, it is a very useful technique which helped visualize very interesting fluid flows in this assignment.

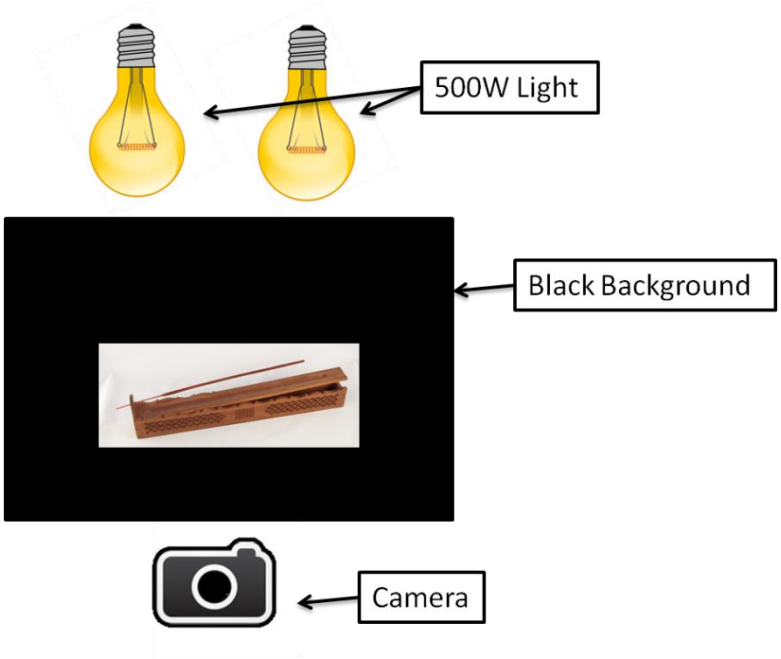

Figure 2: Image capture setup

The setup used was simply an incense stick burning with a black background (Figure 2). I placed the setup in a dark room and lit the smoke with two 500W flood-lights. Because I was using a low aperture and high shutter in order to get the clarity needed, a lot of light was crucial to a successful image. The lighting was directly above the fluid flow and I tried to eliminate any lighting on the background as possible. However, as seen in Figure 3 below, the background was still partially lit.

Figure 3: Original image

As discussed previously, a fast shutter speed was needed to get the clarity of focus without motion blur in the image. In addition I wanted a large depth of field so small apertures were used. Finally, I didn't want to reduce the ISO too much because the intricacies of the smoke could be destroyed by large amounts of noise. However, because of these three preferred settings, I needed a lot of light. Other specifications are shown below.

- Field of view: 10X8 inch
- Distance from object to lens: 1 foot
- Camera: Panasonic DMC-FZ35
- Focal length: 5.8mm
- Image dimensions: each original – 3000x4000 pixels, final – 3225x2329 pixels
- Exposure specifications: 1/250 sec shutter speed, f/3.0, 400 ISO
- Post-processing: image cropping, color contrast – curves, cloaning image irregularities, overlaying color gradient

Conclusion

When I originally sought to capture the beautiful images taken by Graham Jefferey, I thought that it would be almost impossible. However, despite the fact that my images are not as amazing as those taken by Mr. Jefferey, I believe that my goals were achieved. I was able to show the transition from laminar to turbulent flow through the use of incense smoke in ambient air and I produced a very beautiful image. I was especially surprised by the detail seen in the vortex motion and the fact that so many layers of those vortices could easily be seen. If I were to improve the picture in any way, it would

be to retake pictures with even more lighting. I think if enough lighting were used a nice color inverted image could be produced which would have a very different effect than the one I took. The setup is easy enough to do, so I hope to try again in the future.

References

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