Vortex Ring Fog

Figure 1: Final Photograph

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Introduction

The image seen in Figure 1 is the final product for the team third assignment for Flow Visualization class. This was our final team picture, so we wanted to do something a little different. Our goal was to capture a more complicated flow phenomenon, so we chose to look at vortex rings. However, my final image is not directly a vortex ring, it is the “dissolved” vortex ring and was captured during the same photographing session. This picture was created with the help of my team: Brent Bauer, Casey Cooter, Steve Rothbart, and Jacob Chapin.

Experimental Setup

The setup here is super simple. All you need is a black backdrop, light source and a Zero Blaster Smoke Ring Gun. The Zero Blaster uses glycol smoke fluid to create a fog in which it creates the vortex ring out of. This takes all the hassle out of having to generate vortex rings and allows you to focus more on the photos themselves. The specifics of our setup are outlined below in Figure 2.

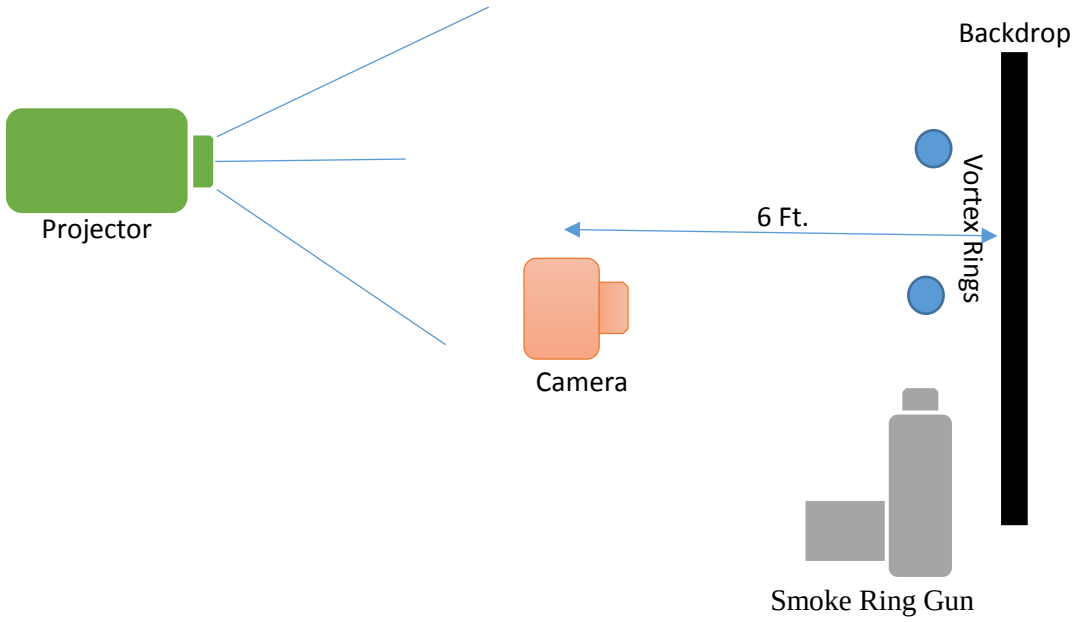

Figure 2: Experimental Setup

To be able to accurately see the vortex rings against the black backdrop, you want a type of direct light to illuminate the smoke. For that we used a projector, this was perfect to keep a consistent bright light throughout all photos. For this setup you need at least two people, one taking pictures and the other shooting the vortex rings. The position of the Zero Blaster Smoke Ring Gun is arbitrary. The distance from the backdrop and the angle you are shooting at changes the perspective the camera sees. To capture the vortex rings fading into smoke (as in

Figure 1), the gun has to be several feet away from the backdrop. We used a variety of different angles to get a good span of images. The camera was placed approximately 6 feet away from the backdrop, this gave a good position to capture the rings at different locations on the backdrop.

Explanation of Fluid Flow

The phenomenon that my photograph is focused around is toroidal vortex (AKA vortex rings). This isn't necessarily what my photo looks like at first glance, however the smoke photographed was an artifact of the instability of vortex rings. In short, vortex rings occur when fluid flows back on itself. This makes a spinning ring around an invisible core, often times trapping another substance (i.e. smoke) inside the ring. These rings are often seen in things like volcanoes, artillery, and marine creatures like dolphins [1].

These vortex rings are surprisingly stable and can travel for a good distance before breaking up. For this experiment, to get the vortex ring to break up on the backdrop, we had to shoot the rings several feet away due to the distance they are capable of traveling. After formation, as the vortex ring translates linearly its vorticity diffuses out of the moving body and into the outer irrotational fluid [2]. This means that the air surrounding the vortex rings absorbs some of its rotational energy as it moves. Eventually, the ring's motion slows to a stop when all its vorticity is deposited into the surrounding wake. At this point the vortex ring is broken up due to viscous diffusion and you will notice smoke (in our experiment) naturally floating apart as seen in Figure 1.

Many of the fascinating curls of the smoke in the final image is due to the vortex rings that created it. In Figure 1, we are looking at a side view of a vortex ring. So the rings were moving from the right to left in the image. Due to the innate twisting of the vortex rings, the smoke had some movement inside and wasn't statically trapped inside. As the vortex ring broke apart, this twisting was seen as it diffused into the surrounding air. The deepest white color was still in a rough ring shape, therefore you see many more curls in the smoke than in other places where it had already diffused and faded away.

Visualization Techniques

For this experiment, smoke was used to visualize the vortex rings. More specifically, to create the vortex rings, as seen earlier, a Zero Blaster Smoke Ring Gun was used [3]. These were able to create accurate and consistent vortex rings. For the lighting we used a standard classroom projector to illuminate the subject against our backdrop. A standard classroom projector can be between 1500 – 2500 lumens. Judging on the intensity of the light used and the ambient light

that existed, the projector was approximately 2000 lumens. Lighting is essential for this experiment or it would be impossible to image the smoke.

Photographic Techniques

There are several choices that I had to make to enable the picture to turn out as expected in the end. We wanted the vortex rings/smoke to be visible but with the background to stay relatively dark. However, shutter speed needed to be relatively high so there wasn't too much motion blur. We wanted to limit motion blur to truly capture the flow of the vortex rings. This was achieved by using a mid-range ISO and shutter speed.

The picture was shot with a Nikon D5500 camera. The setting used were: ISO 2500, shutter speed – 1/125 sec, and aperture- f/7.1. That high of a shutter speed was used to reduce the motion blur that would occur with the shutter open for any longer. A focal length of 42mm was used to get good details of the smoke rising. The original photo has a size (in pixels) of 6000 x 4000, and the edited photo is 2317 x 2826.

As you can see in Figure 3, the original image is drastically different from the final product. However, the post processing done was mostly just cropping. The image was cropped so that beautiful smoke in the corner of the black backdrop could be captured. The contrast and white balance was also changed slightly to bring out the white smoke from the black background. If the flow was centered on the backdrop, more of the flow could have been kept and drastic cropping wouldn't have been as necessary.

Figure 3: Original Image

Conclusion

This assignment gave us a good look into visualizing flow that was moving at a fast pace. It proved to be more difficult than initially thought. Being able to get images with good contrast between the smoke and the background while having minimal motion blur is hard. However, in the end I really like how my image turned out. It wasn't the exact intent at the start, but the flow of the smoke it really interesting. Next time I would love to spend a lot more time perfecting the camera setting to get an image of the actual vortex rings themselves.

References

[1] Team, How It Works. “How Vortex Rings Form.” How It Works Magazine, Future Plc, 26 Oct. 2016, www.howitworksdaily.com/how-vortex-rings-form/.

[2] Maxworthy, T. (1972). The structure and stability of vortex rings. Journal of Fluid Mechanics, 51(1), 15-32. doi:10.1017/S0022112072001041

[3] Rutter, Daniel. “Zero Blaster Smoke Ring Gun.” Zero Blaster Smoke Ring Gun, 10 Aug. 2003, www.dansdata.com/zeroblaster.htm.