Alyssa Berg

Group Project #1

With help from Aaron Coady, Nick Cote, and Sreyas Krishnan

Vortex Rings

Purpose and Context

For the first group project, our group wanted to take a picture of vortices. In order to accomplish this, we chose to take pictures of different fog rings. Fog rings have very intricate physics behind them and have very unique properties. Taking the pictures of the fog rings proved more difficult than the group originally anticipated. After taking hundreds of pictures, only a handful were usable and they still involved very intensive editing.

Flow Apparatus

For the setup of the vortices, we took our pictures in the light and vibration room in the ITLL of the engineering center at CU Boulder since the room was very dark and very few people seem to use it. A schematic of the setup is shown Figure 1.

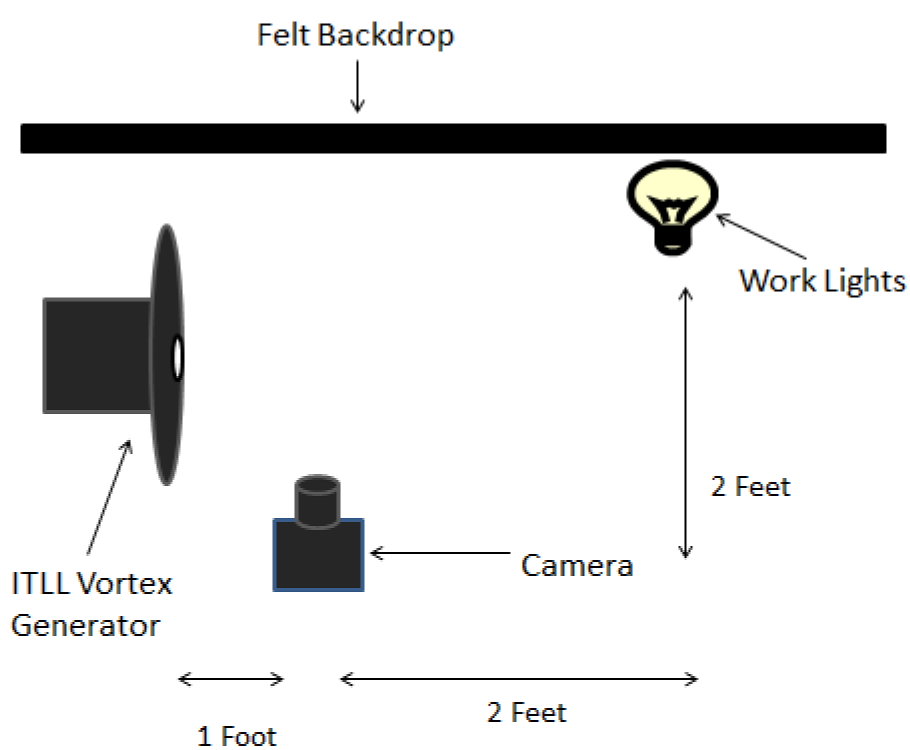

Figure 1: Apparatus Setup

In this set up we used the vortex generator that we found in the ITLL basement. We filled the generator with fog from a fog machine that was filled with water. The work lights were also found in the ITLL and were used as the light source. The vortex generator has several different sizes and shapes of holes that can be used to create different vortices. The one that was used in this picture was of the circle and the approximate diameter of the hole was three inches.

The Physics behind the Picture

Once the vortex generator was filled with fog, it was tapped from behind in order to create a vortex. This was done many times and numerous pictures were taken of the vortices. It is stated that a leading vortex will be created when Reynolds numbers are greater than 6, Re = UD/ν [1]. The velocity (U) can be determined by knowing how far the object travelled in the picture and the amount of time it took to get there. The velocity of this picture was determined to be 5.4 m/s. The diameter of the orifice was measured to 76.2 mm. The viscosity is also known and at room temperature and it is equal to $1.51*10^{-5}$ m^2/s [2]. From these values the Reynolds number was determined to be $27.2*10^3$. This value shows that it is turbulent and that a leading vortex will form.

Another important factor when classifying a vortex is the formation number. This is a dimensionless parameter is used to define the ratio of the length of the column pushing out the fluid divided by the diameter of the orifice. It is also stated from this that the maximum vortex ring circulation time can be found between 3.6 and 4.5. If there is any further fluid discharge, it will not increase the circulation it will merely cause a tail at the end of the vortex [3]. For this picture the length of the pushing column was .45 meters, since this was the length of the column used by the vortex generator. The diameter as stated previously was 76.2mm. This means that the formation number is equal to 5.9. This indicates that there will be a tail formed by the vortex and this was also seen in the picture [4]. Several assumptions were made in calculating these values. These include assuming that the flow is incompressible and that the picture was taken at room temperature and that the temperature of the lights did not affect the vortices.

Photo Specifications

For this picture the field of view is approximately 4 inches by 10 inches. The reason why this field of view was chosen because I wanted to capture the entire vortex ring and show some of the additional fog coming off of the vortex. The distance from the object to the lens was approximately a foot and a half, as seen in the set up picture. The camera that was used was a Sony alpha 230 DSLR camera. The shutter speed was set to 1/60 seconds and the aperture value was set to f/9 and the focal length was 28 mm, the ISO was 400, it was 877 by 1177 pixels, and the flash was also fired in this picture. For this picture the background was a felt backdrop, which proved to be very challenging when editing the picture. Since it was black felt, when I zoomed in on the vortex I was able to see the grainy parts of the blanket and it made the picture appear grainy, but it was not due to anything related to the camera or picture quality. This proved to be the most difficult aspect when I was editing the picture. In order to darken the background without deleting any of the smoke I messed with the curves and moved the bottom left corner over more to the right to darken the background. I also used one of the brush features that was set on a very large size and was on the feather feature to almost paint the background black. I also increased the contrast and noise reduction significantly. In addition to changing the background I also cropped the picture pretty significantly and rotated it 90 degrees.   I did this rotation because I thought it looked like a jelly fish and that gave it a better illusion. The edited and original pictures are included in Figures 2 and 3.

Figure 2: Original Picture

Figure 3: Final Picture

Conclusion

Overall, I really did end up liking my picture; however, I did learn that capturing pictures of fog rings and vortices proved very challenging. It was very difficult to have a picture that was in focus and was clear. One challenge was having the felt backdrop and I learned that in the future I should never use that again. The physics are shown fairly well in this picture, but some of the smoke was made harder to see because of the editing, to darken the background. That would definitely be the aspect that I would want to improve. However, I did end up liking the picture and I did feel like it demonstrated the fluid flow adequately.

References

[1] Cantwell, B. J. 1986 Viscous starting jets. J. Fluid Mech. 173, 159–189.

[2] Munson, B. R., Young, D. F.,Okiishi, T. H., Fundamentals of Fluid Mechanics 4th Edition, 833.

[3] Gharib, Morteza, Edmond Rambod, and Moshe Rosenfeld. "Circulation and Formation Number of Laminar Vortex Rings." *Journal of Fluid Mechanics* (1998): 297-318. Print.

[4] Mohseni, K.,Ran,H. Y. & Colonius, T. 2001 Numerical Experiments on Vortex Ring Formation. J. Fluid Mech. 430, 267- 282.