# Smoke Vortex Rings

Flow Visualization

MCEN - 4228/5228 - 002

April 5, 2010

Levey Tran

Josh Stockwell

Ilya Lisenker

For our second group assignment we decided to photograph smoke vortex rings. In order to accomplish this our team used commercial firework miniature smoke bombs and a vortex generator that was constructed by Ilya. The purpose of this project set up was to capture high quality photographs of vortex fluid flow phenomena. The team originally set out to obtain photographs of a flaming vortex ring, but due to the difficulty in obtaining such a picture and the danger the experiment posed, we decided that high quality photographs of a smoke vortex would be safer, more feasible, and have a high potential to look great with our given setup and equipment. The set up allowed us to capture interesting images of vortex ring flow phenomenon in varying stages of its development.

The vortex generator that we used was built from rigid cardboard with a size of 20”x24”x29”. The corners were reinforced with additional pieces of rigid cardboard. A vinyl membrane was attached to the back of the box in order to be able to generate an impulse on the fluid within the box. ¼ inch diameter bungee cords were attached to the front corners of the box and fed through a hole in the membrane to a pull ring. A 7.5 inch diameter whole was cut in the front of the box to generate the vortex ring. The use of the vinyl membrane and the bungee cords allowed us to modulate the force applied and therefore the resulting speed of the vortex ring, this made it easier to obtain images of well defined vortex rings. The vinyl membrane only needed to be pulled back a few inches to generate excellent quality smoke rings; if it was pulled back too far, the smoke ring would travel to fast and would not develop in time for a good image to be taken. The vortex generator construction is shown in figure 1.Figure 2 shows the set up that allowed for the best smoke ring images to be captured. The experiment was conducted inside a team member’s living room. The smoke rings that were created and photographed varied drastically in size, the smallest rings being equal to the diameter of the hole and the largest rings

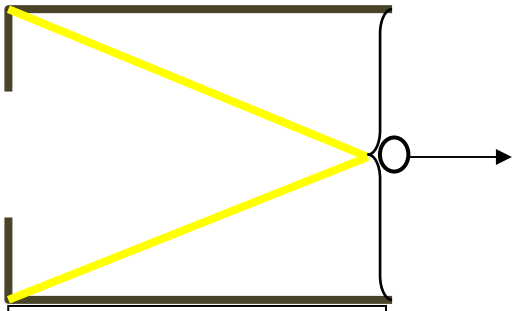

**Figure 1: Vortex ring generator**

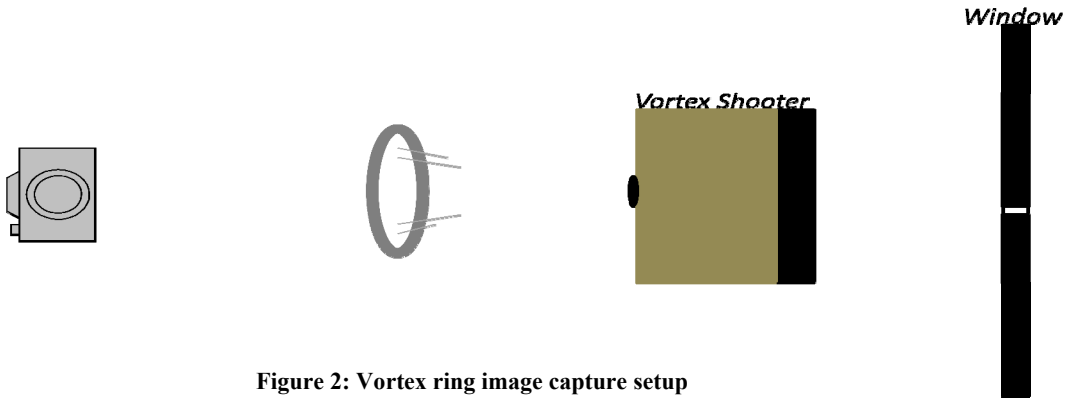


**Figure 2: Vortex ring image capture setup**

reaching approximately two and a half feet in diameter. The smoke rings travel and hold themselves together because of the way they rotate (Small Smoke Ring Cannons, 2006). The vortex generator, when actuated, pushes the smoke out of the inside of the box and through the hole, where the center of the hole has the highest velocity. The center of the ring is pushed and then moves forward and the outer surface is dragged backwards (Why Does Smoke 'Ring'?, 2009). This creates a curling effect of the smoke and keeps the smoke tight and compact.

In order to get enough smoke to have clearly visible vortex rings we used several commercial firework miniature smoke bombs, that were approximately 1 inch diameter each. These smoke bombs were of various colors including gray, green, yellow, blue, and purple. The smoke was not dense enough that the color of the smoke was observable in any of the images taken. We discovered that the best vortex rings were best visualized when they were backlit. Various forms of lighting were experimented with such as using work lights from different angles, typical household lamps, black lights, and red lights. None of these produced results as visually pleasing as having the vortex rings backlight by sunlight. The camera was directed at the opening of the vortex generator. This allowed the vortex rings to be backlit by sunlight through the window, and allowed for the vortex ring to develop as it approached the camera. These two factors combined allowed us to capture some great images of well formed vortex rings.

## Levey's Image

The image was captured using a Canon Powershot G10, which is one of Canon's compact digital SLR. The size of the field of view is approximately 4.5 feet wide and 3 feet tall. The distance from the front of the vortex shooter to the lens was approximately 10 feet and the smoke ring captured in this particular photograph is approximately 7-8.5 feet from the lens. From the camera data given in Photoshop, the focal length of this photograph was 18.1 mm, an aperture value of f/4 was used, 1/125 sec shutter speed, ISO speed rating of 200, lens specifications of 6.1 – 30.5 mm, and no flash was utilized. For the final image, the pixel dimensions were 1432 in the X direction and 1236 in the Y direction. The final image was manipulated in Photoshop by cropping the original photo, using the Curves adjustment tool to darken the picture and adjust the lighting to how I desired, adjusting the Brightness/Contrast values to +81 Brightness and +23 Contrast, and also adjusting the Vibrance values to -19 Vibrance and +2 Saturation.

This image shows a fully developed vortex ring of smoke flowing through air. Before and after the Photoshop adjustments, I really like the both photos (original and the final). The lighting was nearly perfect to fully visualize the smoke ring as it is traveling through the air. It is extremely easy to see and the color contrasts were superb, the smoke ring shape and size was great, the clarity was excellent, and it

was, in my opinion, one of the better photos that we captured. After modifying the original photograph in Photoshop, I also really liked the final image. I liked how the photo gives you an eerie out of space, yet calm and relaxed feeling. The faint black hole in the background that is seen is due to the vortex cannon hole, and makes it look as a dark black moon or planet is in the background. The black and blue color contrast in the image is great because I feel that the shade of blue is nearly fluorescent at the top, and then fades and becomes smoke like and transparent at the bottom. I do dislike the fact that if I were to post this picture somewhere, it might need to be explained that the viewer is seeing a smoke ring head on. This can most likely be related to the absence of any stray smoke, smoking device or lips within the picture. Overall, I think this is an excellent photograph of a fully developed vortex ring and I think that the photograph gives a viewer an eerie but calm feeling.

## Josh's Image

For my image I chose one which showed the vortex ring before it was fully developed. In the image you can clearly see the outline of the vortex but it has yet to develop internally and be fully defined. I chose this image because I thought it was one of the better quality images we had, and also because I feel it shows a different perspective. I think seeing this in conjunction with Levey's image of a fully developed vortex ring helps add to understanding the physics behind vortex rings and how they are created. The original image was much larger and showed the vortex generator box, part of our set up and some of the surrounding living room and windows behind the vortex generator. I wanted to focus solely on the developing vortex ring; therefore I cropped my image to show only the vortex ring. The distance from the camera to the vortex generator was approximately 15 feet.

My image was taken using a Canon PowerShot G10 with a focal length 0f 24.978 mm. I used a shutter speed of 1/125 seconds with an aperture of f/4.4, an F-stop of f/4.5 and and ISO of 400. The image has a resolution of 180 pixels/in. The original image was 4416 x 3312 pixels but was cropped down to 1638 x 1518 pixels. I used a few Photoshop modifications but tried not to overdue it. The first thing I did was crop the image to focus just on the vortex ring. I then inverted the image and used the fade option setting opacity to 100% and choosing the mode to be luminosity. This helped me brighten the vortex ring which I believe made for a better visualization. I then used the Brightness/Contrast tool to set contrast to 100 and brightness to -10. Using Vibrance/Saturation I set vibrance to +20 and saturation to +20. Finally I used Shadows/Highlights to change shadows to 50% and highlights to 10%.

I find my picture very compelling because of how it shows a vortex ring still in development which I think is very interesting, and helps demonstrate the physics involved. I like the colors in my picture but wish they were a bit more vivid. I would have liked to have a little more definition in the

vortex ring itself and I think this could have been achieved if there had been a greater amount of contrast between the backdrop and the vortex ring. I find the image slightly grainy which I don't like but it's not terrible. I didn't think the bungee cord in the upper right hand corner was overly distracting but I got a lot of feedback about taking it out so I would consider doing that next time. I really like the bright white circle from the whole in the box, because of it my image reminds me of an eclipse also. While many people suggested removing the bungee cord I find it interesting how it adds to the lower right to upper left composition technique we learned about in class during the composition lecture. Overall my image is enjoyable to me and I feel it adequately shows the physics while leaving some room for improvement in visualization.

## Ilya's Image

For my image I chose an image taken by Josh. The camera used was Canon G10 set to ISO-400, f-stop 4.5 and exposure time of 1/125sec. Focal length was 25mm or 112.5mm (35mm equivalent). Distance to the face of the box is 12.5 feet. Field of view is approximately 32in. x 43 in. Image was cropped to a size of 1896x1616 pixels. Brightness, contrast and color scheme were adjusted to achieve the desired artistic effect.

The vortex has not fully formed yet showing the entire flow out of the opening of the "generator". The flow approaches the front of the box as a wave but as the flow is stopped by the edge, the fluid inboard of the opening continues to move and the resulting pressure gradient sets up the rotation (Dyke, 1982). Once the vortex ring is formed, it is propelled by its own velocity field reacting against surrounding air and dissipates very slowly due to air viscosity. In our experiments, rings were able to move tree branches at least twenty feet away. In industrial applications, vortex formation is an important field of study in combustion processes weather research as well as flow measurements.

I believe we had a perfect set up to create even better images. It was only an freak accident that limited my time and prevented me from obtaining an even better photograph.

## References:

Dyke, M. V. (1982). Vorteces. In M. V. Dyke, *An Album of Fluid Motion* (pp. 42-43).

*Small Smoke Ring Cannons*. (2006). Retrieved April 4, 2010, from Amateur Science: http://www.eskimo.com/~billb/amateur/vortgen.html

*Why Does Smoke 'Ring'?* (2009). Retrieved April 4, 2010, from Science Hobbyist: http://amasci.com/wing/smring.html