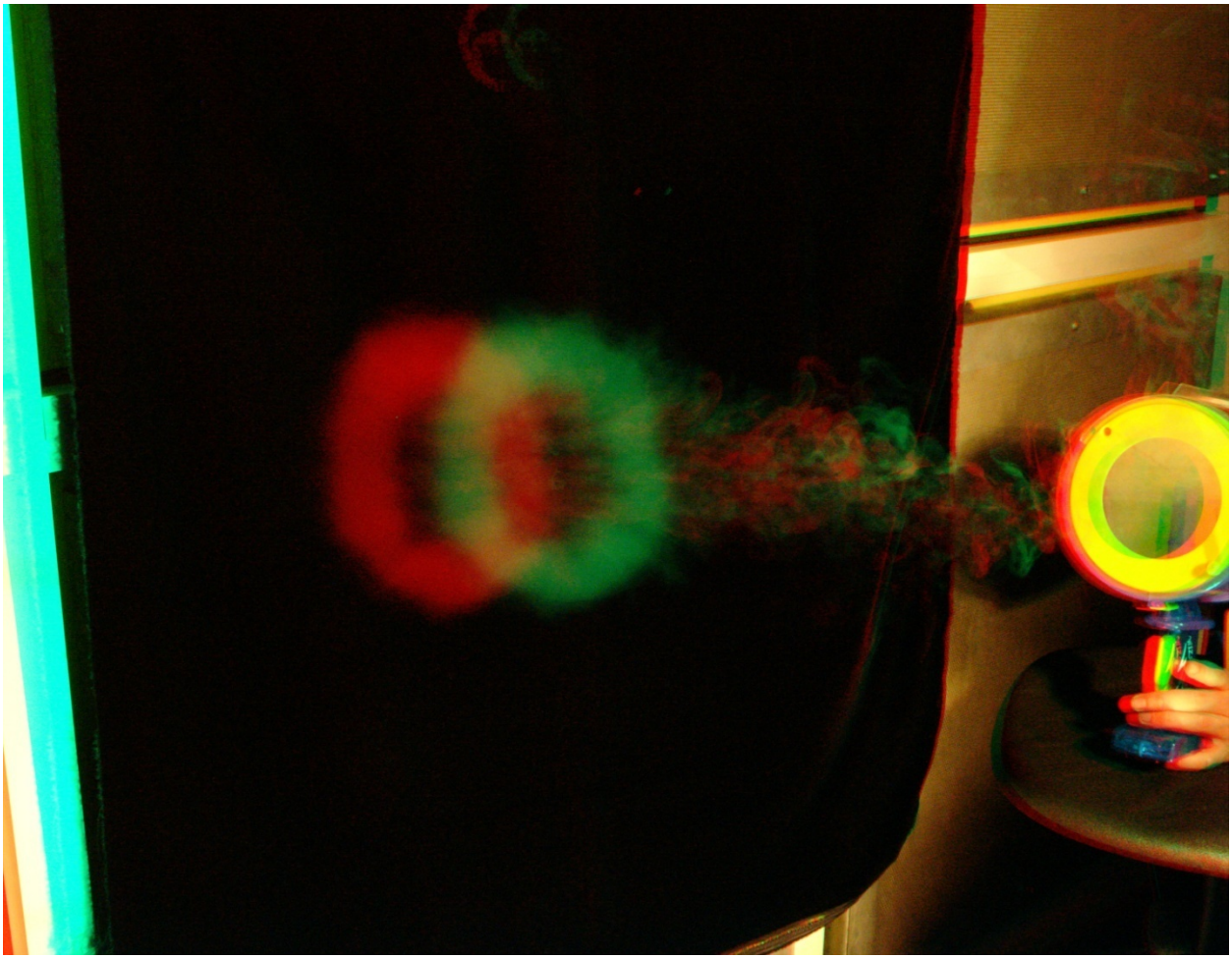
Team Project 3

Three Dimensional Vortex



By

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Image Intent:

The purpose of this image is to visualize a vortex ring in a three dimensional photo. The image is intended to be both beautiful and stimulating and show the physics of a vortex. The vortex is created using fog generated by a fog machine that is ejected from a vortex generator. Fog is used to mark the flow.

Flow Formation:

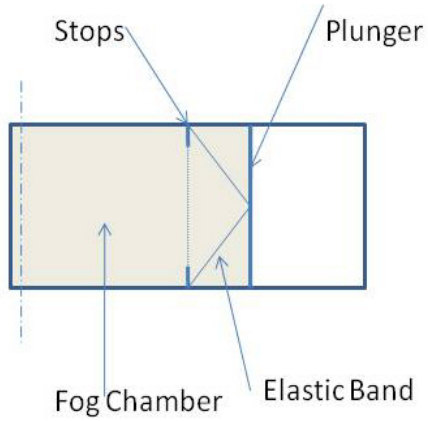

Figure 1 (Top View)

The flow is generated using a vortex generator, which is a toy used to create what can essentially be described as smoke rings. Instead of using smoke for this particular image, the flow was seeded using the fog generated by a fog machine. The vortex generator is a cylinder with a radius of about 4 in. and a length of about 1 ft. There is a fog chamber at the end from which smoke rings are ejected from. The fog chamber has one open end and is closed at the other end by a moveable plunger. The fog chamber is filled with a thick fog with the plunger pulled back about one third of the way. At this point the fog chamber is pointed in the direction of the flow. The plunger is then released and then forced forward until reaching the stops (illustrated in figure 1) by two elastic bands. This decreases the volume of the fog chamber and forces the fog out in the shape of a vortex.

During the imaging of this flow, multiple shots of the same ring were imaged. By calculating the distance and time between the images of the vortex the speed of the flow can be calculated. Using this method, it is clear that the flow is moving at approximately 3 ft./sec. This speed doesn't remain constant due to the flows interaction with the surrounding air. The flow is actually experiencing a negative acceleration, if the positive direction is considered to be moving away from the vortex generator. The velocity at which the air leaves the bucket is inversely proportional to the diameter of the hole

Flow Phenomenon

The vortex ring imaged is created when a plume of fog is ejected from the vortex generator. The air being ejected from the generator is moving at a higher velocity than the ambient air as it moves through it. The moving mass of air experiences higher levels of friction force on its' outer most edges, which causes this layer to be peeled back. The moving mass of air also creates a lower pressure zone at its trailing edge. The higher pressured ambient air forces the layer of fog that has peeled off into the lower pressure zone creating a rotating flow and the toroidal shape.[i] As the vortex ring moves through the air it also increases in diameter. This can be attributed to a loss of air mass due to drag from the surrounding air. The moving air within the vortex ring will have a slightly lower pressure than the ambient air, which will decrease the interchange of gas molecules between the moving air and the stagnant air. This is why the vortex ring will last much longer than after the rest of the plume has dissipated.[ii]

An interesting note in the ideal physics of vortex rings is that there is no net air movement within the fluid itself. The particles on the outer section of the ring move backward and then toward the center, then forward and back down. This overall circular fluid flow appears as if there is a net movement of particles but this is only because the inside of the ring is not always visible. In actuality friction does exist between air and smoke particles. This is a main cause of why over a distance a trail of smoke is often left behind the ring. The smoke on the outside, which is traveling backwards, is subjected to shear force from the surrounding air. Here is where small portions of the smoke disintegrate from the vortex ring. The ring usually travels in a straight line and is able to maintain its shape for quite some time unless other forces or turbulence acts on the moving fluid. [iii]

Three Dimensional Imaging Technique

In order to understand the physics behind three dimensional imaging, it must be understood that even a single human eye by itself is incapable of depth perception. It is because humans have two eyes that they are capable of seeing depth perception. The human brain uses the two slightly different images seen from slightly different angles in order to create depth perception.

Stereo imaging, or three dimensional imaging, can be created using a similar technique. In order to acquire a three dimensional image, two cameras must be used to take a picture of the same object, or in this case, flow, from slightly different angles. The separation of the camera must be proportional to the object distance in a ratio of about 1 to 40.

To view the two different images captured as one single image with the illusion of depth, each eye must be restricted to viewing only one image. In order to do this, the two images are superimposed over each other with altered colors. In one image, all of the red is filtered out and in the other image all of the green and blue are filtered from the image. The viewer must wear glasses with a red filter over

one eye and a cyan filter over the other. This lets each eye only see one of the images and produces a 3 dimensional effect.[iv]

In order to capture the dramatic smoke rings in a three-dimensional photography, having the correct equipment is necessary. John Hart, a guest lecturer for the MCEN 4228 Flow Visualization class assisted our group with the photographic technology. The imaging set up consisted of two identical Sony Cybershot V3 7.2 mega pixel cameras, which were wired together side by side about 18mm apart with one upside down. The images are captured with a Carl Zeiss Vario-Sonnar 2.8-3.7/6-72 Lens and a 4x Optical zoom onto a 1/1.8-inch Super HAD CCD. There is a controller (basically a mini computer) on the right side that the wires are connected to, which allows for one button to trigger both cameras in simultaneously. It is necessary that both cameras be set with the same settings including ISO and Exposure, Shutter Speed, Aperture, Focal Length, and Distance to subject. The Shutter Speed was 10/1000 sec, the Aperture was set to f/2.8, the ISO was 800, the Focal Length was 10.8mm and the Distance to subject was 1.5meters. We used two settings for photos, the first was a single shot that proved to be difficult because the smoke rings moved at varying speeds meaning it was difficult to capture a single ring in a single shot. We then switched the camera to a multiburst mode that took multiple (4) photos in rapid succession. This proved more useful because at least one of the photos had the smoke ring in it. The smoke rings were shot both perpendicular to the lens as well as diagonally directly towards the lens. We hung a black drop cloth as a background and lit with a work light. After taking the photos, we used a free program called Stereo Photo Maker to arrange the photos from the two cameras together. This program is a free download (from the website http://stereo.jpn.org/eng/stphmkr/). There are many options the program software offers to shift, change, and edit the photos in order to create the desired effect. It is important that the 3-D technical requirements are fulfilled; for example, there cannot be a horizontal and vertical shift of one of the photos because the 3-D version will not function properly and it causes the photo to appear blurry and often becomes painful to look at.

My Image

My original left and right images were 3072 x 2304 pixels with a resolution of 72 dpi. The f-stop was f/4 and the exposure time was 1/100 sec with a focal length of 9 mm and maximum aperture of 3. My final 3D picture was compressed to 2955 x 2288 pixels with a resolution of 96 dpi. Using the free software discussed above, I combined the left and right images to create the 3D picture.

Image Likes and Dislikes

I did not do any Photoshop processing because I did not want to manipulate the image and not be able to render it as 3D. I chose this image because of its fantastic display of the trail behind the smoke ring. It was very difficult to get the smoke ring in focus, thus my goal was to see the path of the ring as distinctly as possible. I like how the trail can be seen and how it is clear on the image as to how it forms from the back side of the vortex ring. The smoke dissipates off the ring and then seems to become more concentrated and in focus as you look toward the smoke toy gun. I think fluid physics are

shown, just not as clearly as I would have liked because it was very difficult to get the cameras to focus on the smoke.

Our group functioned well as a team. We imaged various arrangements of smoke. I would have like to spend more time trying to find better methods of creating and imaging the smoke but we were limited in our time because we had to borrow the camera equipment. Overall I learned a lot about how to make a 3D picture and why it is so much trickier than it seems. I think that 3D imaging is fantastic and really makes the interesting have a high sense of reality.

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[i] Experiments with Vortex Rings in Air R. H. Hernández *et al* 2006 *Europhys. Lett.* **75** 743. Online Available: http://iopscience.iop.org/0295-5075/75/5/743/?ejredirect=.iopscience

[ii] "Vortex Ring Structure at Late Stages of Formation" Dazen Fabris Department of Mechanical, Materials, and Aerospace Engineering, Illinois Institute of Technology,Chicago, Illinois 60616, Dorian Liepmann Department of Mechanical Engineering, University of California, Berkeley, California 94720-1740

[iii] "Why Does Smoke 'Ring?" William J. Beaty. Online available: http://amasci.com/wing/smring.html

[iv] "The Art of Stereo Photography" Bob Manekshaw. Online available: http://www.photostuff.co.uk/stereo.htm