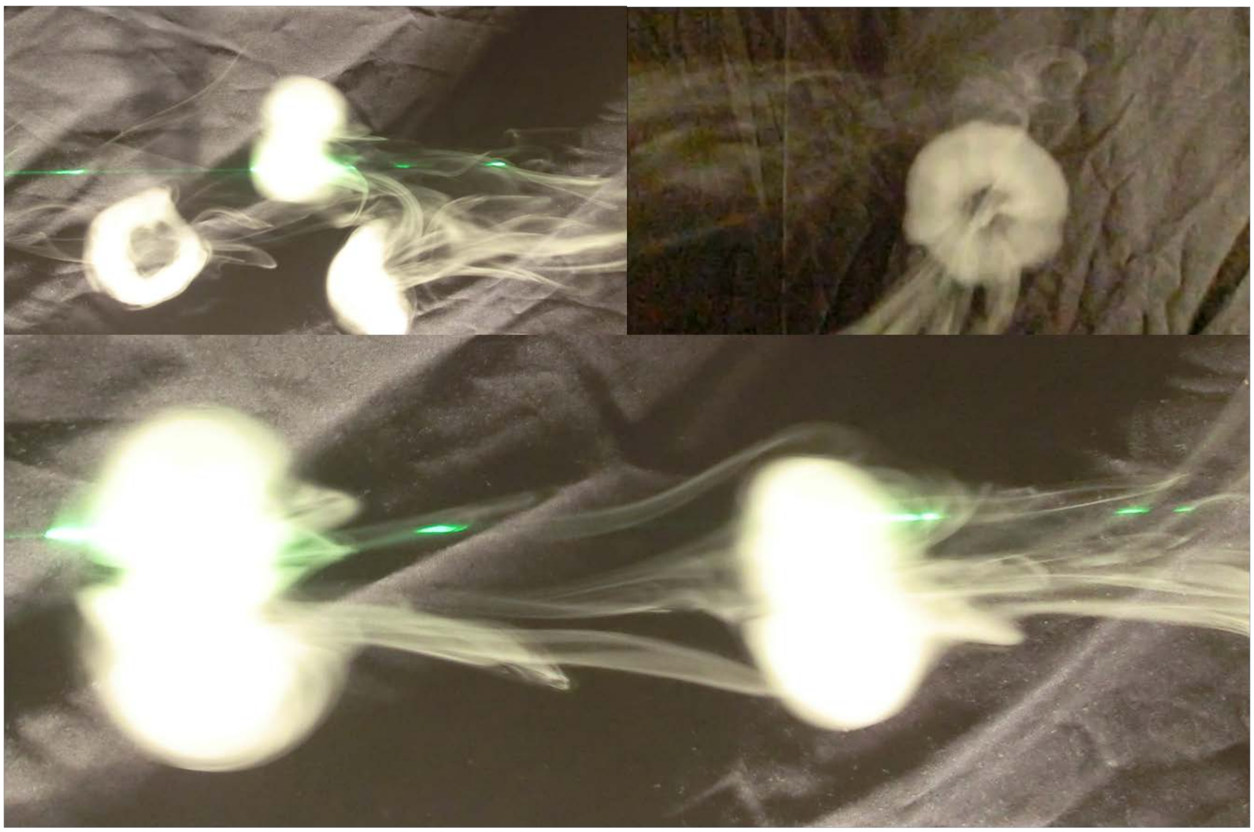
Fun with Smoke Rings

Group 1 Assignment



Kelsey Spurr

MCEN 4151

March 19, 2013

Purpose

This video was made for the CU Boulder Mechanical Engineering course MCEN 4151 Flow Visualization "Group 1" assignment. The intent of this assignment was to work within a random group composed of students from different backgrounds and experience levels, relying on each other to help visualize a desired flow phenomenon. Our team (Group 9) composed of Lotem Sella, Paul Sweazey, Wayne Russell, and Aaron Porras decided to focus on the smoke vortex ring phenomenon. Though our initial shoot turned out some very good images, I decided to shoot some extra high speed videos later with the help of my roommate Cameron Hutchins.

Flow Apparatus

To create the vortex rings the team and I decided to fabricate our own vortex ring generator. The apparatus was built around a 5 gallon Home Depot bucket which had its bottom cut out. Taped over the cut out portion of the bucket was a piece of cardboard with a hole cut out. This design allowed us to easily and cheaply make multiple variations of the hole that created the vortex rings. On the top of the bucket we created a diaphragm made of duct tape allowing us tap on it and create rings out of the cardboard.

The team and I experimented with a couple different hole sizes and configurations, but found for our apparatus a 2-inch diameter hole worked best for us. This hole choice gave us fairly stable vortex rings that ranged from about 2 to 12 inches in diameter.

Tapping on the back of the apparatus created a vortex ring by “injecting a compact mass of fast moving fluid (A) into a mass of stationary fluid (B) (which may be the same fluid). Viscous friction at the interface between the two fluids slows down the outer layers of A relative to its core. Those outer layers then slip around the mass A and collect at the rear, where they re-enter the mass in the wake of the faster-moving inner part.” [1]. When comparing the properties of the fluid within the rings to the properties of the bulk fluid (air) we can see that they are almost equal across the board with the smoke being slightly less dense than the air. This was advantageous for stability of the vortex as it traveled through the air because the vortex didn’t tend to sink or rise.

Though the smoke within the vortex rings has components of its velocity in other directions, if we treat it as a non-rotating solid ring moving through the air at about 1m/s we can estimate it's Reynolds Number. Assuming the smoke in the experiment was about 70°F we find that the Kinematic Viscosity is about 1.52 x 10^-5 m^2/s [2] and the ring is 10cm in diameter we can calculate

$$Re = \frac{UD}{\upsilon} = \frac{\left(1\frac{m}{s}\right)(0.1m)}{1.52 \text{ x } 10^{-5}\text{ m\^{}2/s}} = 6579.$$

Throughout the experiment the vortex rings experienced a couple interactions that I found interesting. First, when a vortex ring impacted a wall. This occurrence really showed how the internal flow within the ring would grab the wall and spread apart until finally it dissipated (below).

Another interesting phenomenon observed was when a slow moving vortex ring was impacted by another quick moving ring (below). This collision between rings usually resulted in the unraveling of both rings.

While continuing to observe ring collisions, an interesting result was found when two vortex rings, one traveling quicker than the other deflected off of each other (below).

Finally, throughout the entire experiment there were numerous occurrences of what I deemed to be Widnall Instability within the rings (below).

Visualization Technique

To provide the best contrast to the vortex rings we used white smoke on a black matte background. To create the smoke we used a smoke machine that my roommate owns. The background was wrinkled black curtain we hung up on a wall. I felt the added texture of the wrinkles added detail to the dynamics of the rings impacting the wall, but others found it distracting. Special caution was taken to keep the conditions of the air in the room as static as possible as to not interrupt the natural flow of the rings.

For the lighting, all of the ambient lights in the room were switched off and a single light source was used. The light was a 500 Watt construction light positioned a few feet from the wall on the floor focused on the black curtain as shown below. For a few clips I used a green laser to try and highlight the trails of the rings.

Photographic Technique

As previously stated, I choose to record this phenomenon through high speed video at 240 frames per second (or fps). The camera used was a Casio EX-ZR100 which shot 240fps at 432x320 pixels. This resolution was a bit lower than desired leaving some detail out, but still delivered the point effectively. The high frame rate was important to the video because it allowed the playback to be slow enough to really see what was really happening within the vortex rings. Assisting me by shooting the vortex rings, Cameron Hutchins, I was able to move freely and catch every angle I wanted. Post processing was done in Windows Live Movie Maker where the clips were trimmed to size and stitched together. During that process the text and music was added as well. The music was The Glitch Mob's "We Can Make The World Stop", which was purchased legally.

Reflection

I thoroughly enjoyed how my video turned out. I feel that the high speed video really was effective in slowing the vortex rings down and show the physics of the phenomenon. For improvement to my video, I would use a higher quality high speed camera that could capture more detail. To develop this idea further I would experiment with different mediums like water.

[1] "Vortex Ring." Wikipedia. Wikimedia Foundation, 18 Mar. 2013. Web. 19 Mar. 2013.

[2] "Air - Absolute and Kinematic Viscosity." *Air - Absolute and Kinematic Viscosity*. N.p., n.d. Web. 19 Mar. 2013.