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Team #1 Photo - MCEN 5151
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The third project of the Flow Visualization class was to develop an image working with a team. The goal of this assignment was to provide more complicated image by collaborating with team members on ideas and setup of flows. My idea was to capture an image of a smoke ring produced by a commercially available toy known as an Airzooka, Figure 1. Team members that assisted with this visualization are Blake Buchannan, Felix Levy, Aaron Lieberman, and Gabriel Paez.

Figure 1: Airzooka[1]

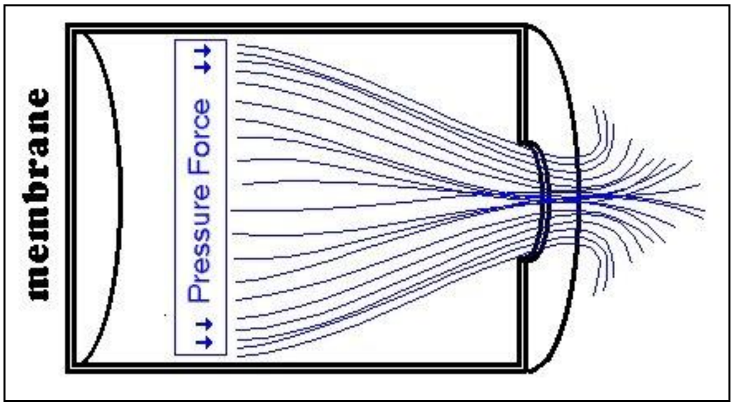
The setup for the image was fairly simple. A black backdrop was made on a wall using garbage bags. A BBQ grill was used for producing the smoke for the Airzooka. Using a high speed camera, multiple videos were taken with the smoke ring coming out of the Airzooka, parallel to the backdrop. There was too much light outside for a very visible and clear smoke ring with the backdrop. So we resulted to using a darker background that could be moved easily, the lid to the BBQ grill. We were able to get videos of a defined smoke ring with a person holding the lid approximately 2 meters from the Airzooka. The speed of the smoke ring is estimated to be 4 meters per second, and the diameter of the ring is roughly 0.3 meters. With the outdoor air temperature of 20°C, the Reynolds number was calculated as the following:

$$Re = \frac{UL}{\upsilon} = \frac{\left(4\frac{m}{s}\right)(0.3m)}{1.51\ x\ 10^{-5}\ m^2/s} = 8\ x\ 10^4$$

Figure 2: Smoke Vortex Ring in front of lid

This number puts the vortex ring into the turbulence regime, which was expected. The resulting ring is pictured in Figure 2.

The Airzooka is an air vortex cannon that fires doughnut-shaped air vortices, and it consists of a short and broad barrel with a slight taper, closed by a flexible diaphragm at the larger end.[2] When the diaphragm is pulled back to increase the volume in the barrel and released, air rushes out towards the opening as can be seen with Figure 3. During ejection, the air jet rolls up into a toroidal spiral (ring) and in the process, entrains some of the ambient fluid into the spiral as is shown in Figure 4.[3]



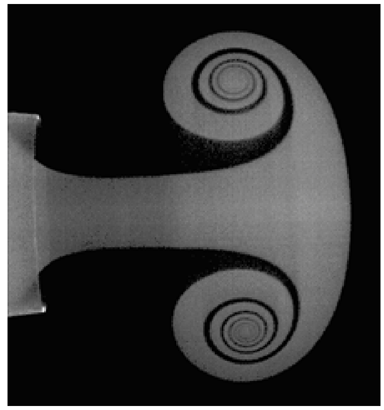


Figure 3: Flow of Air from Barrel of the Air Cannon[4] **Figure 4: Cross-Section of Vortex Ring[3]**

Smoke vortex rings' behavior are described by Helmholtz's Vortex Theorems which state the following[5]:

- Vortex lines move with the fluid.
- The strength of a vortex tube (its circulation) is constant along its length.
- A vortex tube cannot end within the fluid. It must either end at a solid boundary or form a closed loop – a vortex ring.
- The strength of a vortex tube remains constant in time.

From looking at the multiple smoke vortex ring videos, it is not hard to show the third bullet is easily observable. The vortex tube creates a ring since it cannot end in a fluid, and the vortex rings do not end in the fluid such as water or air but end when they hit a boundary such as a wall. Since fluids are not inviscid, the ring will eventually dissipate, but it may take a while depending on the medium and external factors such as wind or currents.

The size of the field of view is approximately four feet square. The high speed camera used was a Casio Exilim Zr-100, and the video was taken at 240 frames per second. The video resolution is 1440 pixels wide and 1080 pixels high. The video was modified using Windows Live Movie Maker program. The colors and contrast were manipulated to better define the smoke ring, but none of it produced a clearer image. So the video was not changed in regards to color or contrast. The speed of the video was reduced by a half to 120 frames per second since the smoke ring was moving so fast.

The image reveals that an air vortex is really created by the Airzooka. Unfortunately I do not like the poor quality of the smoke ring caused by the bad lighting and poor selection in background. The combination of the two made for a less than impressive image. This was definitely a learning lesson! I did fulfill my intent by capturing a smoke vortex ring, but there are many improvements that can be made for a better quality video and image.

References

[1] Picture fromThinkGeek.com at http://www.thinkgeek.com/product/60b6/.

[2] Air Vortex Cannon on Wikipedia: http://en.wikipedia.org/wiki/Air_vortex_cannon.

[3] Fluid Entrainment by Vortex Rings, Experimental Fluid Dynamics Laboratory, Department of Mechanical Engineering, Southern Methodist University: http://lyle.smu.edu/~pkrueger/vrentrainment.htm.

[4] Vortex Rings, The Woodrow Wilson Foundation Leadership Program for Teachers, http://www.woodrow.org/teachers/esi/1999/princeton/projects/fluid_dynamics/vortex.html.

[5] P. K. Kundu, I. M. Cohen, and D. R. Dowling. Fluid Mechanics, Fifth Edition, 2012. Academic Press.