Flow Visualization
MCEN 5151

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Introduction:

Unique flows can create some very beautiful images. This is especially the case with Karman Vortex Shedding. Karman Vortex shedding occurs in the turbulent zone after a fluid hits a cylindrical object. A good example of this can be seen in Figure 1, notice the alternating swirl pattern. While this phenomenon was our approach when creating an image, Nicholas and I started playing with different flow rates of water and noticed unique patterns when the flow rate was quickly turned off. This is what created my image.

Figure 1 Example of Karman Vortex Shedding[1]

Image:

The image was taken on March 21st 2012 in the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado at Boulder. The ITLL has many resources which students may use including an open channel water flume. Using the flume and a horizontal cylinder fixture, created by Nicholas Travers, we were able to pump food dye through tiny holes in the top and bottom of the cylinder while water flowed past. An accurate image of the setup can be seen below in Figure 2, additional setup images can be found in the appendix. Controlling the flow rate of the water allowed us to change the Reynolds number which in turn changes the type of vortices present.

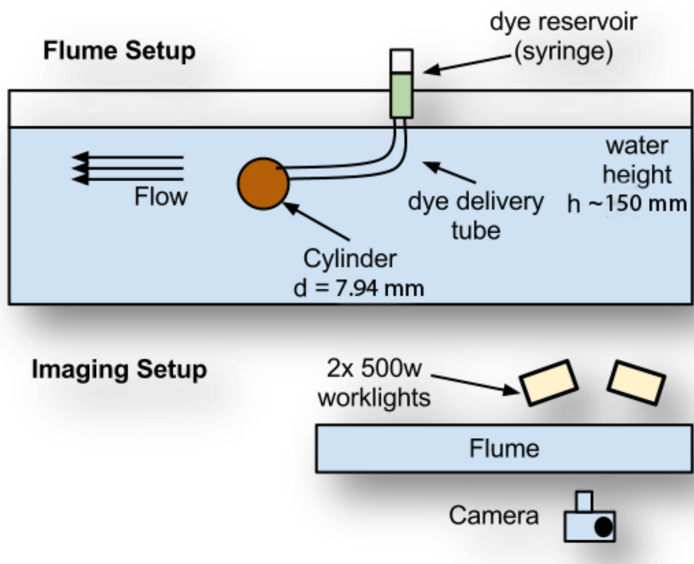

Figure 2 Initial Setup for Image

Physics of Phenomenon:

Knowing that the Karman Shedding Vortex relies on the Reynolds number, calculating the Reynolds number is necessary to compare our results with scientific research. The following equation calculates the Reynolds number around a smooth cylinder.[2]

$$Re = \frac{D * U}{v}$$

The diameter of the cylinder is represented by D in this equation, while U represents the flow rate of the fluid. V is the kinematic viscosity of the fluid. The diameter and kinematic viscosity stay the same throughout the experiment. The only changing variable is the fluid velocity which was measured. The average volume flow rate achieved was .34 Liters/sec. Knowing the height (150mm) and width (76mm) of the of the flow allows us to calculate the velocity. The average velocity is around 30 mm/sec or 0.03 m/sec. The kinematic viscosity for water at room temperature is $9.025*10^{-7}$ (m^2/s).[3]

$$Re = \frac{D * U}{v} = \frac{.00794m * \ .03\ m/s}{9.025 * 10^{-7}\ \mathrm{m}^2/\mathrm{s}} = 263.9$$

Using Williamson's *Vortex Dynamics in the Cylinder Wake*[4], it can be noticed that the Reynolds number generated in the experiment closely resembles theirs and can be seen in Figure 3. This means a good range for optimal photographs is ideally between a Reynolds number of 150 and 300.

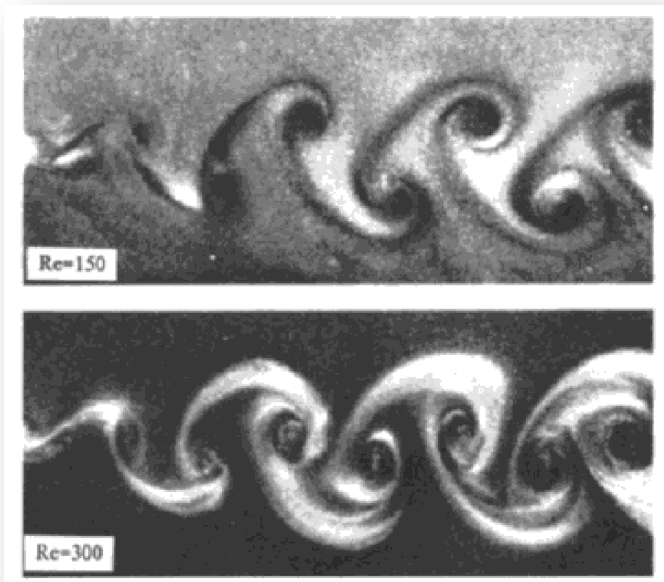

Figure 3 Karman Vortex Shedding with corresponding Reynolds number[4]

Photographic Technique:

The following is a list of the camera settings used to take the photo.

- Size of the field of view: 6 x 14 inches
- Distance from object to lens: 3 inches
- Lens focal length: 6.4mm
- Type of camera: Nikon COOLPIX P7100
  Original (3648 x 2736)
  Edited (3420 x 1557)
- Exposure Specs: Aperture: f/5.6
  Shutter Speed: 1/800
  ISO 400

Figure 4 Orginal Image

Figure 5 Processed Image

The original and processed image can be seen above. The processed image was cropped around the dye to create a strong focus on the flow. The image was then inverted to make the original green dye become pink and the background to darken. The Plexiglas that holds the horizontal cylinder can be seen by the edges of where it ends. These were removed using the stamp tool in Photoshop CS5.

Commentary:

I enjoy the movement shown in this image. It almost feels as if it is in space. I chose not to remove the white in the bottom corner to bring in more contrast to the image. Thinking of it as in space makes the white corner almost appear as if it is earth. The Reynolds number of the water really defined the vortices seen in the image and corresponds to other research done by Williamson[4].

References:

1. (Accurate picture of Karman Vortex Shedding) <http://viaductconstruction.blogspot.com/2009/05/tacoma-bridge-disaster.html>

2. Sumer, Mutlu. *Hydrodynamics Around Cylindrical Structures.* World Scientific Publishing Company, 1997. 1st chapter. Print.

3. (Kinematic Viscosity of water at room temperature) <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html>

4. Williamson, C.H.K. "Vortex Dynamics in a Cylindrical Wake." *Fluid Mechanics* . 28 (1996): 477-539. Web. 5 Apr. 2012. <http://www.annualreviews.org/doi/abs/10.1146/annurev.fl.28.010196.002401?prevSearch=authors%3A%28C.H.K+Williamson%29&searchHistoryKey=>.

Appendix:

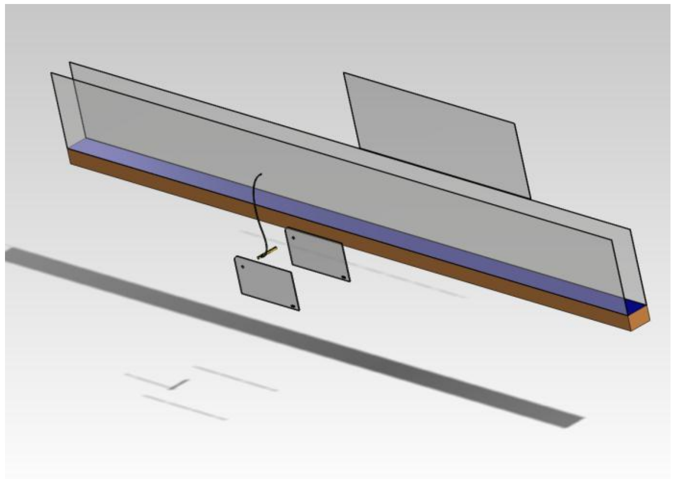

Figure 6 Exploded view of flume and horizontal cylinder

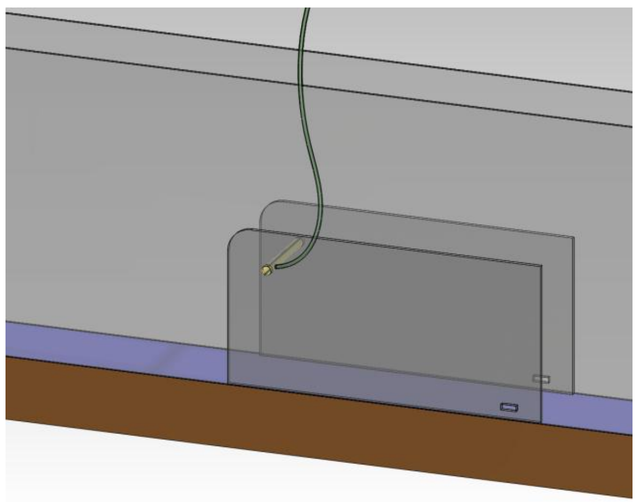

Figure 7 Close up view of horizontal cylinder set up, notice the way the Plexiglas stands hold the cylinder

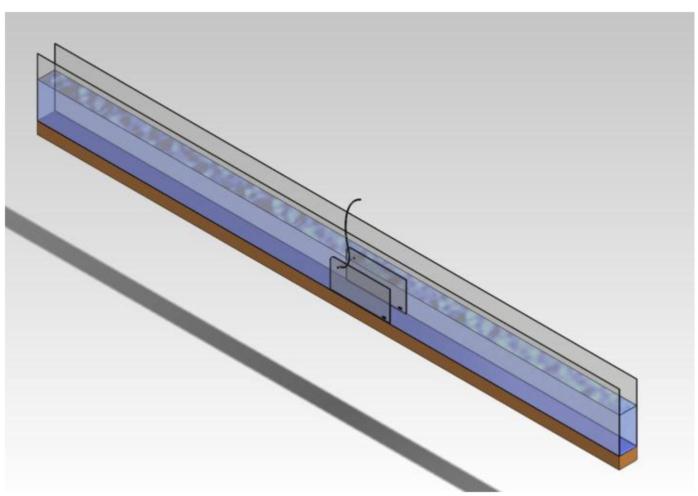

Figure 8 Overall view of setup with water added