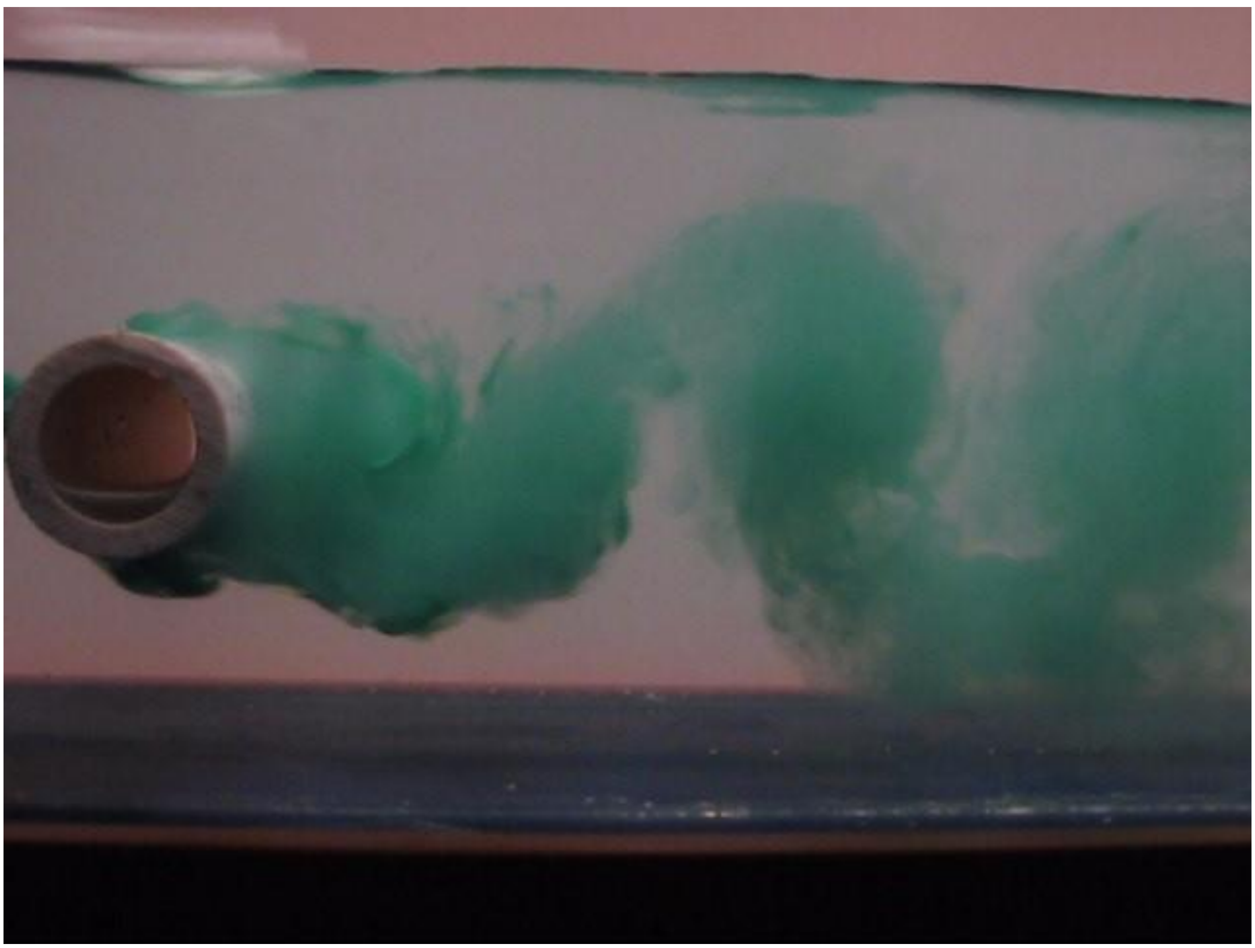
von Karman Vortex Street

Flow Visualization: Group Project 1

March 15, 2010



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The purpose of this first group project was to collaborate with other people to help generate creativity for our images and techniques, as well as to do distribute talents and equipment among the class. This particular video illustrates a von Karman Vortex Street generated by uniform flow over a cylinder. This was done by injecting dye into the flow just in front of the cylinder. At first a mixture of dye and water was used, but the dye would break up too quickly to see the vortices, so a mixture of milk and dye was used instead. This helped the vortices say together better, but at the cost of losing some of the definition and details of the vortices.

The apparatus used for this image was a small section of ½ inch PVC pipe, a syringe with a tube for injecting the dye, and an open artificial water channel known as a flume. The PVC pipe was cut to fit snuggly in the flume so that it wouldn't move from the pressure applied by the flow around it. The water was allowed to begin flowing through the channel and then the PVC was submerged approximately halfway between the upper and lower surfaces of the water. Then the dye was injected slightly upstream of the center of the cylinder at a rate of approximately 10 mL per minute. Calculating the Reynolds number for the flow can be given by the equation:

$$Re = \frac{\rho V D}{\mu}$$

Where ρ is the density of the fluid, V is the velocity of the flow past the cylinder, D is the diameter of the cylinder, and μ is the viscosity of the fluid. The outer diameter of the PVC pipe was 2 centimeters. The viscosity of the milk is estimated to be 2.0 cp or $2*10^{-3}$ kg/m*s and the density of milk is about the same as water at 1000 kg/m^3 .[1] The velocity of the flow through the channel was estimated at 20 cm/s. Inserting these numbers into the above equation yields a Reynolds number of 2000. This means that the flow was in the region where it transitions from laminar flow to turbulent flow. The Strouhal number is also an important dimensionless number that can be used to determine the frequency of the vortex shedding off of the cylinder. The Strouhal number, denoted St, is given by the equation:

$$St = \frac{fL}{V}$$

In this equation, f is the frequency of the vortex shedding, L is the characteristic length, and V is the velocity of the fluid. For $250 < Re < 2*10^5$ the Strouhal number can be determined from the empirical relationship:

$$\frac{fL}{V} = 0.198 * (1 - \frac{19.7}{Re})$$

Using previous parameters and the Reynolds number calculated previously, the frequency of the vortex shedding in the video is 1.96 Hertz and the Strouhal number is 0.196. [2]

The video was taken in the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado. The visualization technique used is injected dye into a flow. All of the materials were provided by the University, except for the PVC pipe which was purchased at Home Depot. The area of the ITLL in which the flume is located is illuminated by florescent lights, but those lights alone were not nearly enough. Two 500 Watt work lights were used for backlighting and a 250 Watt light was placed on top to shine down onto the cylinder. This provided adequate lighting to fully visualize the vortices.

The camera used to capture the video was a Canon PowerShot SX120 IS. This is a 10.0 megapixel digital camera, and would be classified as a point and shoot camera. The field of view in the video is about 4 inches. The distance from the lens to the transparent wall of the flume was about 6 inches. The camera was shooting at the highest resolution it had, which was 640 x 480 pixels at 30 frames per second. For the exposure the video had a +/- value of -1 meaning that it was one stop underexposed. The light setting used on the camera was tungsten. The video it was imported into Final Cut where the contrast was increased slightly, and titles were added. Music originally composed by Bach was also added via the editing software.

As the artist responsible for this video, there are a few things that I would like to say. The image clearly reveals the phenomenon that we were trying to capture. As stated earlier, some of the details of the vortices were lost with the addition of the milk, but the details can be seen in the pictures that were submitted by the other members of our group, Jacob Gigliotti and Joseph Eisinger. For this reason I would say the intent of the video was fulfilled. If I were to try and repeat this and improve on it, I would experiment with other types of dyes to see if there was a way to capture the vortices on video without losing the definition.

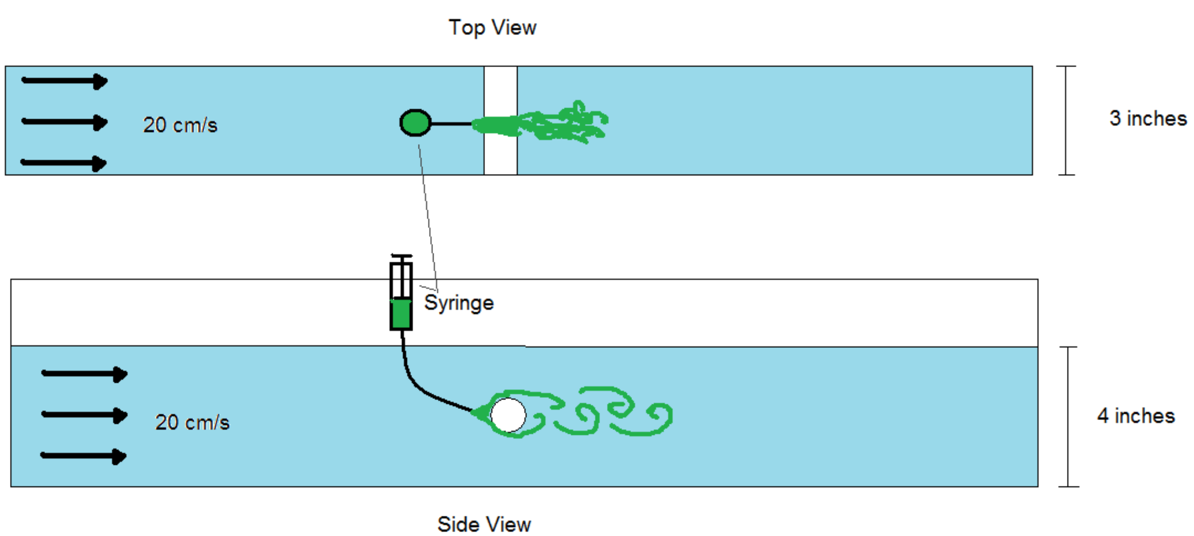

Figure1

Work Cited

[1] http://www.brookfieldengineering.com/education/applications/laboratory-milk.asp
[2] http://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_vortex_street