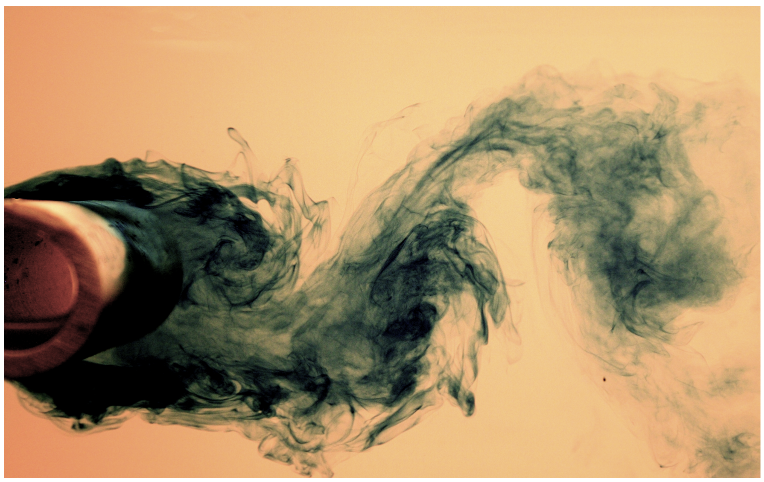
Group Project 1



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Flow Visualization Group Assignment 1

March 15, 2010

The purpose of this assignment was to work in a group and explore the art and science of flow visualization. Our intention for this assignment was to explore von Karman vortex streets. We wanted to use the flume and gain some experience with seeding a flow with dye. I am pleased with the images we produced and the flow physics apparent in them.

The flow shown in my image was produced in the flume. Dye was injected from a syringe into the flow as it streamed past a cylinder, as seen in Figure 0.1. The syringe used had an exit hole of approximately 7 mm^2. The flow of water was about 7.6 cm wide and 10 cm deep. The dye was ejected at the same speed as the flow in the flume, which is estimated to be 0.25 m/s. The Reynolds number of the flow over the cylinder was found to be:

$$Re = \frac{V \cdot L}{\nu} = \frac{0.5(m/s) \cdot 1.9(cm)}{1.004E-6(m^2/s)} = 4500$$

While the Reynolds number of the flow upstream was :

$$Re = \frac{V \cdot L}{\nu} = \frac{0.5(m/s) \cdot 7(cm)}{1.004E-6(m^2/s)} = 17000$$

The flow seen in my image appears to be rather turbulent, with the dye indicating quite a bit of mixing. The Reynolds number with respect to the cylinder does not indicate greatly turbulent flow, but considering the Reynolds number for the flow in the entire flume, we see that in fact all of the flow is turbulent. This causes the dye to mix with the water just as it is released from the syringe, and contributes to the mixing that is seen throughout the flow.

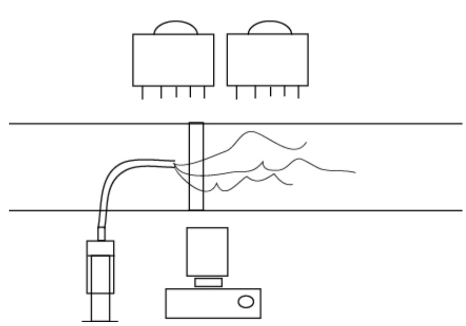

Figure 0.1: Sketch of flow apparatus.

The flow phenomena seen in the picture is known as von Karman vortex streets, so named because of the similarity of the staggered vortices with footprints in a street[1]. These staggered vortices of alternating rotation direction result from instability in the wake behind the cylinder, which sets in when the Reynolds number exceeds 40[4]. This process happens as eddies form behind the cylinder and begin to oscillate, as the Reynolds number exceeds 80[1]. Then, the eddies break off periodically, from either side of the cylinder, and in doing so, another eddy forms on the other side[1]. The ramifications of this effect can be profound in the real world. The vortices actually cause oscillating lift on the object behind which they flow, which can cause vibrations[1]. If this vibration is at the resonant frequency of the object in the flow, vibrations can amplify out of control and result in catastrophic failure. This is a major concern in engineering which must be considered. Additionally, if the frequency of the oscillations is in the acoustic range, this phenomena can be responsible for sounds such as the "singing" of telephone wires[1].

The frequency of the vortex shedding seen is a function of the Strouhal number, and is calculated as:

$$S = \frac{n \cdot d}{V} = \frac{1.8(1/s) \cdot 1.9(cm)}{0.25(m/s)} = 0.14$$

where n is the frequency, d is the diameter of the flow, and V is the velocity of the flow[1]. I calculated the frequency in the flow to be 1.8 Hz which gives a Strouhal number of 0.14. The Strouhal number characterizes the oscillations seen in the flow, describing the ratio of inertial forces to unsteadiness in the flow[3]. The low number of our flow indicates that the flow is very unsteady.

The visualization technique that I used for this photograph was blue dye. The dye that we used was food coloring in water, so the properties of both fluids can be considered the same. We used a concentration of 15 drops per 100 mL. The syringe that we used had an extended tube, which allowed us to position the exit hole just in front of the cylinder, using a wire wrapped around the tube. The lighting in the photo is backlighting from two halogen lamps, shining on an opaque white pane of plexi-glass, as well as the ambient light in the room and another halogen light directly above the flow shining down on it.

The photographic technique that we used was very simple and straight forward. We set up a tripod right in front of the flume, with the camera pointed directly at the flow. The size of the field of view of the image is approximately 60 cm^2. The distance from the lens to the object was approximately 10 cm, and the focal length was 41 mm. The type of camera that we used was a Canon digital camera, an EOS 40D. The original image file was 3888 x 2592 pixels, and the final image is 2765 x 1727 pixels. The exposure specifications were shutter speed of 1/1000 seconds, ISO 800, and F number 5.0. I processed the image slightly in Photoshop, cropping the image and then increasing contrast.

This image reveals the flow physics of a von Karman vortex street. I am very pleased with the phenomena seen, it is just what we set out to do. I am also very pleased with the quality of the photograph, Jake is in my group and is an apt

photographer. In the future, I would like to experiment with other flow seeding techniques, perhaps we could have seen a longer street of vortices if the dye did not break up so quickly. Overall, I am pleased that we produced a scientific flow with some interesting qualities.

Bibliography

[1] Cohen, Ira M., and Pijush K. Kundu. Fluid Mechanics, Fourth Edition. New York: Academic, 2007. Print.

[2] "Kármán Vortex Street -." Wikipedia, the Free Encyclopedia. Web. 13 Mar. 2010. <http://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_vortex_street>.

[3] "Strouhal Number." Engineering ToolBox. Web. 14 Mar. 2010. <http://www.engineeringtoolbox.com/strouhal-number-d_582.html>.

[4] Yang, Wen-Jei. Handbook of Flow Visualization. New York: Taylor & Francis, 2001. Print.