Get Wet Project

MCEN 4228: Flow Visualization

Sean Hulings

The intent of my Get Wet Project was to effectively produce and document a flow that displayed the transition of laminar flow into that of turbulent. Also, my goals were to capture an image that was both aesthetically pleasing to the eye and that clearly demonstrated the physical phenomena at hand. For my purposes, a flow technique using fog produced by the sublimation of CO2 forced through a long cylinder into still air was used. The concept for this idea was

partly influenced by memories of watching fog flow out of a humidifier as a child, particularly the smooth laminar flow I saw coming out of the spout.

After some experimentation, a final flow apparatus as seen in Figure 1 was used. A plastic container filled with warm water, moderate sized chunks of dry ice (frozen CO2), a tight fitting lid, and paper tubes were used to generate and direct the CO2 fog. Based on the dimensions of the tube and the fluid characteristics of CO2, it is possible to theoretically determine where the flow should be laminar or turbulent. The dimensionless quantity that describes this is called the Reynolds number. Equation 1 describes how it is calculated where U_∞ is the free stream velocity, D is the characteristic dimension, μ is the absolute viscosity, and ρ is the density.

$$R_D = \frac{U_\infty D \rho}{\mu} = \frac{(0.3)(0.0762)(2.1657)}{12.59E-6} = 3932$$

A Reynolds number of 3932 was calculated. This number falls within a zone (2000-4000) where the flow transitions between laminar and turbulent. This theoretical prediction seems to agree with the observations seen in the flow image.

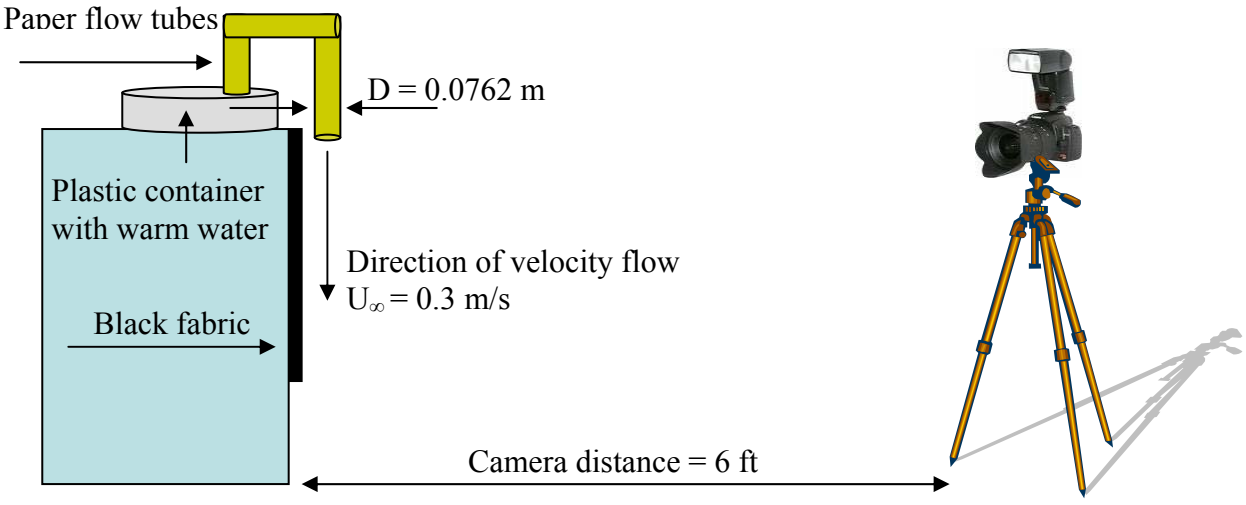

Figure 1: Schematic of flow apparatus

With CO2 fog as my visualization technique, one of my biggest concerns was how to control or manipulate the flow so that my intended phenomena could be seen. Since the density of CO2 is heavier than air, the fog has a tendency to fall downwards. Given this fact, I felt directing the fog through tubes that eventually pointed downwards for an extended length would allow a better formation of laminar flow before it exited the tube. The fact I was dealing with white fog also brought up background and lighting issues. A black fabric background was used to better contrast the whiteness of the fog and remove distracting elements. Since I intended to stop the motion of the flow, plenty of light was needed. A flood light and a strobe were used.

Photographic Technique	**Value**
Size of field of view	60 in^2
Distance from object to lens	6 ft.
Lens focal length	92 mm
Type of Camera	Canon EOS Digital Rebel (6.3 megapixel)
Aperture	f/4.5
Shutter speed	1/250 sec
ISO setting	100

Table 1: Image properties

All of the important image properties can be seen in Table 1. A relatively fast shutter speed was used in order to freeze the flow at one instance. Several Photoshop techniques were used in order to enhance the image. First the contrast levels were adjusted which dramatically improved the CO2 fog. Next, the picture was transferred into Grayscale to further enhance the contrast of the white fog and black background. The image was then cropped around the area of interest. There were a few areas that still contained noise or reflections from the flash. The brush tool was used to remove these irregularities.

The image reveals a nice transition between laminar and turbulent flow. This phenomenon is specifically seen just as the CO2 fog leaves the paper tube. The flow is very

smooth and then abruptly begins to turn turbulent where the formation of vortices can be seen. I was happy that the theoretical predictions closely matched the observation seen in the image. One problem that I ran into was reflection of light from the black fabric background. If I were to do this experiment again, the use of a more expensive black suede backdrop might lessen this effect. One direction that I might take to develop this flow idea further would be to introduce objects for the flow to interact with, possibly a cylinder.

http://www.efunda.com/formulae/fluids/overview.cfm
http://en.wikipedia.org/wiki/Carbon_dioxide
http://www.colorado.edu/MCEN/flowvis/galleries/2006/assignment1/Ladtkow.pdf