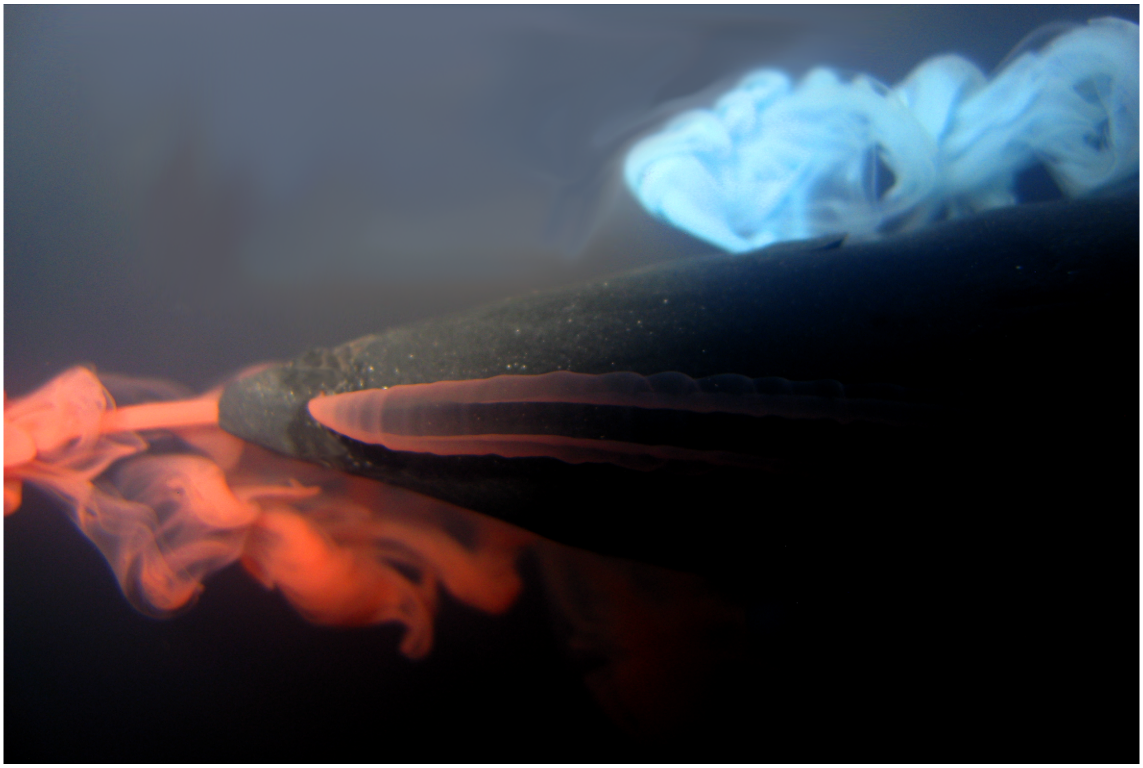
MCEN 5228- Flow Visualization



Assignment: Team Project 3
By: Stephen Lepke
Professor Jean Hertzberg
4/28/2010

Depicting water traveling through a controlled environment can illustrate many interesting things about fluid flow. Fluid traveling over different shapes and forms illuminates how the fluid reacts to different geometries and thus, help researchers and fluid dynamic researchers learn more about their behavior. This picture was taken for the third team project for Professor Hertzberg's Flow Visualization class for the University of Colorado at Boulder. The team members included Terese Decker and Ilya Lisenker. The intent of the picture was to capture an image of how fluid may flow past a cone such as the nose of a jet or of the space capsule. This picture required a lot of experimental setup and our team ran into some technical problems executing the setup, yet overall we did get some good images. The picture's intent was also to show a dramatic difference between the lit part of the image and the darker part of the image, showing the contrast between the flows.

There was a large amount of experimental setup needed for this image. The shape was made out of sculpy and formed into a hollow cone. This cone was about 4 inches in length and has a final base diameter in 2 inches. The cone had 1/8" aluminum tubes inserted through the inside of the cone in order to deliver the dye through the surface of the cone. In order to not block up the tubes with sculpy, small wire protruded from the tube and out through the surface. The sculpy was then baked to harden the sculpy into its final form. After being baked, the wires were then taken out. Next, the cone had to be set up in the flume. A small wooden pole was placed in the back of the cone and then a metal rod was attached to the wood pole to mount the cone. This can be seen in figure 1. Next the dye injection tubes were connected to the aluminum tubes; these tubes were connected to an apparatus that held the dye fluid in 5 syringes as seen in Figure 2. The dye (food coloring mixed with 2% milk) coming out of the cone tip was red, the next two pores ejected blue die, and the last two pores ejected green dye. The mounting rod had a platform attached to it that sat on top of the flume, and the syringe dye setup was clamped to the side of the flume. Black felt was the back drop of the picture, and halogen lights were placed in the back to light object.

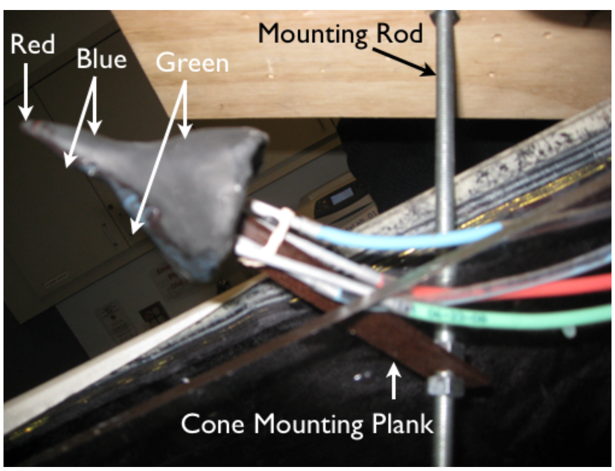


Figure 1: Cone Setup

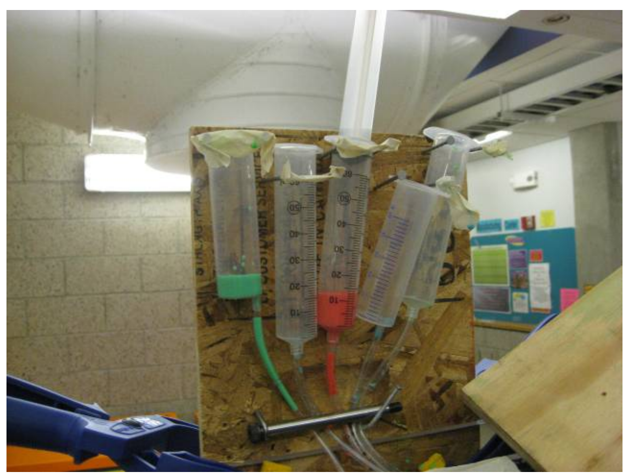


Figure 2: Syringe Dye Setup

The physics of the fluid flow of water over the cone shows both laminar and turbulent flow physics. The incoming water was traveling at .1 m/s and for the most part the flow was laminar over the cone. However the flow coming out of the pores is turbulent. The reason for this is that dye is being gravity fed and since the distance from the dye reservoir and the pores is about 2 feet, there is too much hydrostatic pressure driving the dye flow. This pressure has caused the dye to come out as turbulent, thus creating the seen flow. The flow coming out of the nozzle is originally coming out as laminar, but then as it encounters more of the moving flow, it reverses direction and becomes turbulent. Small vortexes can also be seen coming out of this flow. Vortexes are caused by two different adjacent fluid layers traveling at different velocities[1]. For this flow, the dye and the incoming water make up these two layers generating some of these vortices. The next flow is the red flow coming out the side near the cone's tip. Here one can observe the undulations of the dyed flow. This flow very shows small undulations caused by small vortex phenomenon trailing alongside the cone. Lastly, the blue dye also shows turbulent flow as the high pressured dye is injected into the flow. The rest of the pores did not eject dye due to kinks in the feed tubes and also clogs in the flow path due to manufacturing defects. The dye is flowing at the same rate as the water because the density of the dye (milk) is similar to that of water and thus follows the fluid particle path. Figure 3 shows the flow direction of the incoming fluid. The Reynolds number of the incoming fluid can the ejected dye fluid are different. It can be calculated by the equation below. The kinematic viscosity of water is 1.00* 10^-6 m^2/s while the milk was assumed to have a density very similar to water. The velocity of the incoming fluid was .1 m/s and the velocity of the milk was estimated at 1.5 m/s. Lastly the dimensional length of the water was .10 m (length of the cone) while it was estimated to be .002 m for the outlet cone dimension[2]. This yielded a Reynolds number of the water is 500 while the dye had a Reynolds number of 3,000.

$$RE = VxD/\upsilon$$

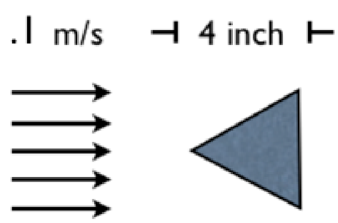


Figure 3: Flow Description

The visualization technique used to capture this image involved careful timing using my Canon Digital Elf point and shoot camera and using the macro function. The background was lit up by lights so as to illuminate as much of the object as possible, however due to the glare of the flume this light had to be hidden behind a black velvet cloth so as to minimize the glare. Even by doing this, the glare had to be photo-shopped out in post image processing. This picture was taken under particularly interesting lighting, where I accidentally had my camera's flash on. However, after taking the picture with the flash on, I realized that I was able to create a very interesting lighting gradient on the image and decided to experiment with this technique. I also used the macro setting on the camera to get a close up and detailed picture, however the camera was hard to focus as it was trying to focus on the moving water more than it was the cone in the flume.

The photographic technique of the image includes many of the technical aspects already mentioned. The field of view is about 5 inches long, and the flow patterns included everything from laminar to turbulent flow. The camera used was an 8 megapixel, point and shoot Canon Digital Elf. There is some motion blur since the field of view is small and the flow (especially for the dyes) are moving at a fast rate; however, the overall motion blur was estimated to be around 2%. The rest of the photographic specifications are listed in Table 1 below.

Table 1: Image Specifications

Make:	Canon		
Model:	Canon PowerShot SD850 IS		
Date Time:	4/20/2010 – 10:02:32 AM		
Shutter Speed:	1/60 sec		
Exposure Program:			
F-Stop:	f/8		
Aperture Value:	f/8		
Max Aperture Value:	f/2.7		
ISO Speed Ratings:	80		
Focal Length:	5.8 mm		
Lens:			
Flash:	Fired		
	No strobe return detection (0)		
	Auto mode (3)		
	Flash function present		
	Red-eye reduction		
Metering Mode:	Pattern		
Camera Data 2			
Pixel Dimension X:	3264	Y:	2448
Orientation:	Normal		
Resolution X:	180	Y:	180
Resolution Unit:	Inch		
Compressed Bits per Pixel:	1		
Color Space:	sRGB		

The intent of the image was to capture flow moving past a cone and trying to see the stream lines evolve over the shape. Due to many technical and manufacturing difficulties, I did not gain the exact image I wanted but I did make some beautiful images that showed similar flow phenomenon over the cone. The image colors make a statement of boldness and chaos, yet still simplicity and tranquility. I cropped the image a little and erased the flash, but other than that, photoshop was not used extensively. My favorite part is seeing the detail of the jet as it comes out of the cone. The variation of the color contrast and the light contrast adds an element of mystery that makes the picture particularly beautiful and interesting. Overall, I am pleased with this final image.

References:

Cengel, Yunus; Boles, Michael. Thermodynamics, An Engineering Approach, 7th ed. McGraw Hill Publishing, New York: New York. 2006.

Engineering Toolbox: http://www.engineeringtoolbox.com/ (4/26/2010)

Original Photo: