Group Project 1 - The Flume

Flow Visualization
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Introduction

The purpose of this assignment is to capture an image of fluid dynamics over a submerged obstacle in order to observe the fluid flow phenomena. To accomplish this goal, the Armfield Open Channel Water Flume is utilized to provide a laminar water flow across the channel bed with adjustable flow velocity and slope of the flow (upstream or downstream). When water flows across a submerged complex obstacle, the laminar flow is disrupted but it is difficult to visualize the flow characteristics of a clear liquid such as water. Therefore, as a visualization technique food coloring is injected into the fluid flow to visualize the behavior of the fluid as it flows across a complex surface and the detail will be discussed later on in this report.

Experimental Setup

Figure1: The water flume setup.

A picture of the Armfield Open Channel Water Flume is shown in Figure 1, which is located at the ITLL basement. The water flume has a 2.5m x 76mm x 250mm channel bed along with a jacking arrangement permits the slope of the bed to be adjustable. The water level in the working section of the flume is controlled by an overshot weir arrangement at the exit. A white curtain is placed on the backside of the channel bed which acts as a background for a better view of the image. In order to get sufficient light, two high-powered 500 watt halogen lamps are used to illuminate the environment in addition to fluorescent ceiling lights. An obstacle is submerged into the channel bed to disturb the flow behavior, and the shape of the obstacle is a complex

sinusoidal plastic block. The flood coloring will be injected into the water flow in the flume through a plastic tube by a piston device in order to provide a consistent injection velocity. Some of the variables that are controllable are listed below:

- Velocity of fluid flow
- Inclined or flat fluid flow
- Submerge different obstacle in the flow to change the phenomena of flows

Visualization Technique

In order to visualize the behavior of the fluid flow, technique of adding visible component will be used. The visible component that is being used in this experiment is flood coloring because of its high visibility and it does not disturb the flow. Red flood coloring is chosen because it provides a distinct contrast on clear water.

Photographic Techniques

The camera used to take the image was a Canon EOS Digital Rebel XT with 8.0 Megapixel. Some of the details of the photographic techniques are listed below:

- Size of field of view – 5 in by 5 in
- Distance from object to lens – 6 in
- Lens focal length and other lens specs:
  - Focal length – 41.0 mm
  - ISO light sensitivity of 400
- Type of camera – Canon EOS Digital Rebel XT 8.0
- Exposure specs
  - Aperture – 6.3
  - Shutter speed – 1/125 sec
  - F-Stop – 9.0

Figure2: Swirl - Original Image

Figure3: Swirl - Final Image.

Adobe Photoshop is used to process the image shown in figure 3, which is the final image. The bottom and the sides of the image on figure 2, which is the original image, are trimmed for any unnecessary distraction of the image. Some adjustments have been made to create a more dramatic image, and they are:

- Curves – First, the color curves were auto adjusted. This took the yellow background and made it whiter.
- Color Balancing – The midtone color levels were adjusted so that it was set at – Red: -100, Green: +9, and Blue: +100. The Shadows were adjusted in a similar way with Red: +2, Green: +100, and Blue: +75.
- Brightness Contrast – Contrast level is increased to +30 to bring out the contrast of the fluid and the flood coloring
- Rubber stamp to remove flash reflection in Swirl image and surface reflection on Ribbon
- Last the image was cropped for a more astatically pleasing view.

Figure 4: Slideshow of Fluid Progression.

Fluid Dynamics

The fluid velocity is estimated at 0.5 in/s and the flow is assumed to be fully developed laminar flow upstream of the submerged obstacle due to the consistent channel dimensions and relatively slow velocity. The Reynolds Number was calculated from the channel dimensions, flow velocity, dynamic viscosity, and fluid density at room temperature and was found to be around 1000.[1] This is well below the transitional boundary number. From the time incremental images of figure 4, the generation of the vortex in the final image can be observed. As a result of the no-slip boundary condition the leading edge of the food coloring slows down and begins to travel slower than the fluid directly above it. The fluid velocity at an approximate height of 2 inches above the

submerged obstacle approaches the free stream velocity. This differential in velocities causes circulation and rotation as the dye trail begins to curl downwards.

Additional Images:

Figure5: Ribbon – Original Image.

Figure6: Ribbon - Final Image.

Different velocities of the dye injection were also explored and can be seen in figure 5 and 6. With a faster injection velocity the dye remains separated from the submerged surface and travels into the free stream. The interaction with the laminar fluid flow of the channel causes a continuous series of multiple vortices on the upper boundary of the dye marker. The circulation is caused by the differential in velocities between the

free stream and the injection velocity. This becomes more chaotic as the dye travels down stream and begins to diffuse in the water.

Conclusion

The images in figure 3 and 4 clearly illustrated the behavior of fluid flow over a submerged obstacle. When fluid flows across an obstacle, the fluid is disturbed and a vortex shape of the flow is formed. The positive aspects from the images are the clear streamline flow of the vortex along with a nice contrast between the red flood coloring and the clear water. The least positive aspects from the images are the fabric weave of the white curtain background of the flow that gives a non uniform distraction from the image. Overall, we were able to visualize the fluid behavior over a submerged obstacle, so the intent of this assignment is fulfilled. One way to improve the image is to use a light colored construction paper as the background instead of the white curtain to provide a better image. Further development of this project can be done by submerging different obstacle to create different phenomena of the fluid flow.

References

[1] Reynolds Number Calculator used from

http://www.efunda.com/formulae/fluids/calc_reynolds.cfm

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Image Assessment Form
Flow Visualization
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Assignment: Group 1 Date: 03/15/2006

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Instructor assessment
Intent was realized	√	
Effective	+	
Impact	+	
Interesting	+	
Beautiful	+	
Dramatic	√	
Feel/texture	+	
No distracting elements	~	
Framing/cropping enhances image	+	

Flow	Your assessment	Instructor assessment
Clearly illustrates phenomena	√	
Flow is understandable	+	
Physics revealed	√	
Details visible	√	
Flow is reproducible	+	
Flow is controlled	+	
Creative flow or technique	√	
Publishable quality	√	

Photographic technique	Your assessment	Instructor assessment
Exposure: highlights detailed	+	
Exposure: shadows detailed	+	
Full contrast range	+	
Focus	+	
Depth of field	+	
Time resolved	√	
Spatially resolved	~	
Clean, no spots	~	
OK, simple print	√	
Mat	NA	
Mounting	NA	

Report		Your assessment	Instructor asssessment
Describes intent	Artistic	√	
	Scientific	+	
Describes fluid phenomena			
Estimates appropriate scales	Reynolds number etc.	√	
Calculation of time resolution etc.	How far did flow move during exposure?	√	
References:	Web level	√	
	Refereed journal level	X	
Clearly written		+	
Information is organized		+	
Good spelling and grammar		+	
Professional language (publishible)		√	
Provides information needed for reproducing flow	Fluid data, flow rates	√	
	geometry	√	
	timing	√	
Provides information needed for reproducing vis technique	Method	+	
	dilution	+	
	injection speed	~	
	settings	√	
lighting type	(strobe/tungsten, watts, number)	+	
	light position, distance	X	
Provides information for reproducing image	Camera type	+	
	Camera model	+	
	Field of view	+	
	Focal length	+	
	aperture	+	
	shutter speed	+	
	film type and speed	NA	
	# pixels (width X ht)	√	
	Photoshop techniques	+	
	Print details	NA	
	"before" Photoshop image	+	