MCEN 4151: Flow Visualization

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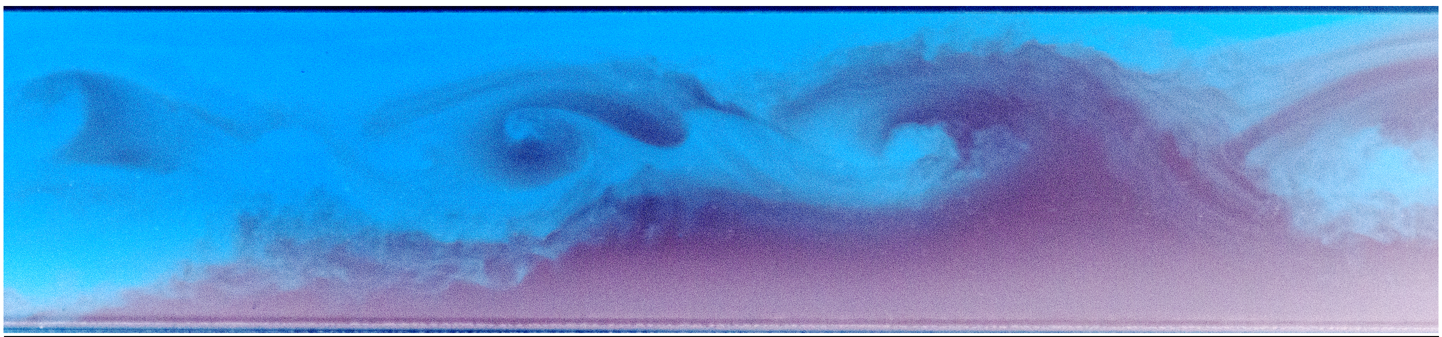

Flow Visualization: Team 3rd Image

Purpose:

The purpose of this image was to capture the Kelvin-Helmholtz Instability caused by two fluids of differing densities sliding along an interface between the two fluids.

Kelvin-Helmholtz Instability:

The Kelvin-Helmholtz Instability occurs when a discontinuity in the tangential velocity causes two fluids of differing densities to slide along an interface between them. The shear flow caused by this discontinuity causes the interface between the fluids to become an unstable vortex sheet that then rolls up into a spiral. This roll up is caused by oscillations in the fluid due to the shear flow. Think of the fluid as oscillating like a sinusoidal wave form when the fluids first begin to rub against one another, as the fluids continue to interact pressure in the concavities (the troughs) of the sinusoidal wave form become higher then the pressure in the convexities (the peaks) of the waveform. Due to this pressure differential the oscillation in the fluid grows. The upper portion of the sheet is carried higher into the upper fluid and the lower portion of the sheet is dragged farter into the lower portion of the sheet. As the waveform is stretched it hits a point where the front of the waveform becomes to taunt that it rolls up at the interface. This roll up occurs in the direction that corresponds to the direction of the vorticity of the mixing layer.

In our experiment we have a layer of fresh water lying on top of a layer of salt water. The density gradation between the two fluids is such that the addition of motion to the system causes the Kelvin-Helmholtz Instability to occur. The discontinuity of the tangential velocity was simulated in this experiment by tilting the test set up so that the two fluids were forces to slide along each other. The vortex sheets caused by this motion can be seen in the blue colored plumes that spiral into the red fluid seen in Figure 1. Figure 1 shows my image with out the color-inversion, to help demonstrate our set up. My final image can be seen on the title page of this report. The direction of the vorticity can be assumed to be to the left since the rolls in the fluid are occurring in that direction.

Figure 1: Non-Color-Inverted Kelvin-Helmholtz Image

Set-Up:

Materials:

- 10 Gallons Fresh Water
- 100 Grams Salt
- Red and Blue Food Coloring

- Kelvin-Helmholtz Set Up – Provided by Dr. Scott Kittelman (Described in next section)

Kelvin-Helmholtz Set-Up:

For this project my group worked with Dr. Scott Kittelman, a researcher for the Department of Atmospheric and Oceanic Sciences (ATOC), at the University of Colorado Boulder. Dr. Kittelman researches experimental geophysical fluid dynamics. Due to the nature of his research Dr. Kittelman constructed a set up that allowed him to easily replicate Kelvin-Helmholtz Instabilities in his laboratory. Dr. Kittelman graciously allowed us to borrow his test set up.

The set up consists of a long thin Plexiglas tank with a tube that allows water to flow into the tank and a small hole with a plug to allow air to escape. See Figure 2 for more details.

Figure 2: Kelvin-Helmholtz Set Up

To create the two fluid layers necessary for this test our group dissolved 100 grams of salt into 5 gallons of fresh water to create our more dense fluid, pure fresh water would be used as the less dense fluid. We then used food coloring to color the salt water blue and the fresh water red to help highlight the different fluid layers. Once the salt had completely dissolved the fluid was allowed to sit for about two hours to insure no air bubbles remained trapped in the liquid. Then fresh water was slowly laid into the tank. Once about half the tank was filled with the red fresh water a layer of salt water was slowly layered under the fresh water. This process had to be completed very slowly so that the two fluids would not mix. The entire fill process took about 3 hours. Once the tank was completely filled both ends were sealed and the tank was left to sit over night. The entire set up process took about 5 hours. The tank with the layered fluids can be seen in Figure 3.

Figure 3: Kelvin-Helmholtz Tank Filled with Fluid. The Less Dense Water is Red; the More Dense Salt Water is Blue.

The next morning our group arrived and set up the lights needed for us to photograph this experiment. Once our lighting was set Scott helped us tip the tank up to a height of 16 inches. This was calculated before the test was run to give us a great enough angle to create the flow necessary to create the instability. Once the tank was secured at the desired high the set up sat for about 10seconds before the fluids began to slide along each other. Once the fluids began to slide the instability was created for about 10 seconds before the fluids reached equilibrium again and we could no longer see the roll ups.

The tank was then returned to its original resting position. After the tank had sat for about 10 min the experiment was run again. While we were still able to generate roll ups the second experiment was not as dramatic as the first run. My image was from the first experiment run.

Image Information:

Table 1: Image Specifications

Focal Length	Exposure	f/	ISO
100.0 mm	1/800 sec	2.8	800

Camera Model: Canon EOS REBEL SL1
Image Size: 1584 x 3456
Resolution: 240 Pixel Per Inch

Post Processing – I cropped and rotated this image since the original image was taken with the tank at an angle. I also added more contrast between the red and blue in my image and then inverted the colors. I then used clone stamp to get rid of a few air bubbles that were shown in my image.

Reflection:

This image took much longer to create and process then I had originally planned. If I were to redo this image I would like to be able to spend more time on this experiment so that I could change the lighting and play around with varying densities to create different sized plumes. I would also add more food coloring to both liquids to help add more contrast between the two fluids.

Special Thanks:

Special thanks to Scott Kittelman for letting us use his laboratory and equipment for this set up.

Works Cited

"Kelvin-Helmhotz Instability." *Kelvin-Helmhotz Instability*. N.p., n.d. Web. 12 Dec. 2015. <http://hmf.enseeiht.fr/travaux/CD0001/travaux/optmfn/hi/01pa/hyb72/kh/kh_theo.htm>.

Matsuoka, Chihiro. "Kelvin-Helmholtz Instability and Roll-up." *Scholarpedia*. N.p., 12 Sept. 2014. Web. 12 Dec. 2015. <http://www.scholarpedia.org/article/Kelvin-Helmholtz_Instability_and_Roll-up>.

Flow Visualization
Spring 2013

Name(s): Kelsea Anderson

Assignment: Team 3rd Date: December 7, 2015
Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

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

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

Photographic/video technique	Your assessment	Comments
Exposure: highlights detailed	√	
Exposure: shadows detailed	√	
Full contrast range	√	
Focus	√	
Depth of field	√	
Time resolved	√	
Spatially resolved	√	
Photoshop/ post-processing enhances intent	√	
Photoshop/ post-processing does not decrease important information	√	

Report		Your assessment	Comments
Collaborators acknowledged		√	
Describes intent	Artistic	~	
	Scientific	X	
Describes fluid phenomena		X	
Estimates appropriate scales	Reynolds number etc.	X	
Calculation of time resolution etc.	How far did flow move during exposure?	~	
References:	Web level	~	
	Refereed journal level	NA	
Clearly written			
Information is organized		~	
Good spelling and grammar		~	
Professional language (publishable)		X	
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	~	
Provides information for reproducing image	Camera type and model	√	
	Camera-subject distance	X	
	Field of view	√	
	Focal length	√	
	aperture	√	
	shutter speed	√	
	Frame rate, playback rate	√	
	ISO setting	√	
	# pixels (width X ht)	√	
	Photoshop and post-processing techniques	√	
	"before" Photoshop image	√	