Get Wet

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Flow Visualization – Spring 2014

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I. INTRODUCTION

The purpose of this assignment was to capture a picture of fluid phenomena. The fluid phenomena explored in this report is known as the Umbrella Instability or Rayleigh-Taylor instability. The umbrella instability can be seen in the final image by mixing dye in cold water. Much experimentation was explored before identifying the best way to capture this phenomenon and the techniques will be described later in the report.

II. FLOW APPARATUS

For this experiment an irregular shaped vase with very smooth flat walls was used to avoid distortion. Below in figure 1 you can see the setup to take the image. The background consists of a white poster board to eliminate any distracting elements.

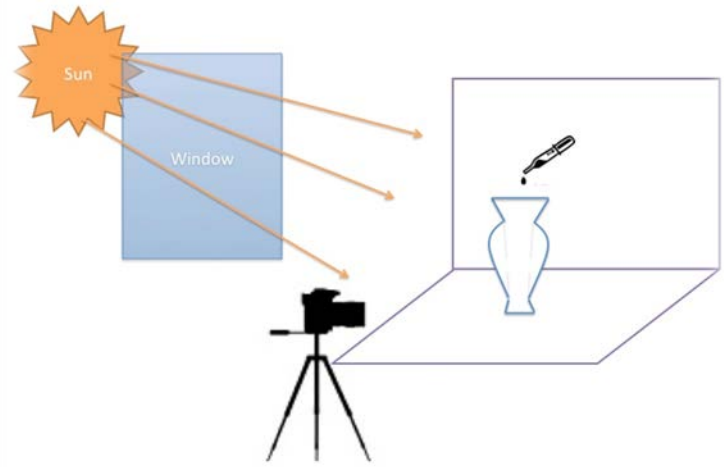

Figure 1: Flow Apparatus Schematic

The flow being captured in this image is known as the Rayleigh-Taylor instability. Rayleigh-Taylor instability occurs when two fluids of different densities push against one another. In the case of the India ink and water the Rayleigh-Taylor phenomenon is occurring due to gravity rather than an acceleration of a lighter fluid into the denser fluid. In the image, there is a streamline initially; this is a result of water having a negligible density compared to the India ink. Finally the bag instability and the vortices form as the fluids begin to intermix.

By analyzing the Froude number the ration of inertial to gravitation forces can be defined. If Froude's number is large the inertia dominates in the suspension drop. In the case with India ink Froude's number can be seen below, where U_d is settling velocity of the India ink

(the image was taken in a continuous shooting mode at 1/8 of a second per shot and in the image the drop moved approximately 3mm per frame), *g* is gravity and *R* is the radius of the initial drop of ink:

$$Fr = \frac{U_d}{\sqrt{gR}} = \frac{.025\ \frac{m}{s}}{\sqrt{\left(9.81\frac{m}{s^2}\right) * (.003\ m)}} = .145$$

In the case of the India ink and water the gravitational forces dominate the inertial forces. According to Bosse, T. et al [1] when the Reynolds number is low ($Re_d << 1$) the suspension drop retains a spherical shape while settling, whereas when the Reynolds number ranges between 1 and 100 the suspension drop undergo a shape change which can also be known as the umbrella instability. The spherical drop begins to flatten and the particles in the back settle quicker than the particles in the front creating the sort of umbrella look. The Reynolds number for the India ink in the water can be seen below:

$$Re = \frac{U_d R}{v} = \frac{.025\ \frac{m}{s} * (.003\ m)}{1.004 * 10^{-6}\ \frac{m^2}{s}} = 74.7$$

Using the kinematic viscosity at room temperature[2] the Reynolds number can be determined to be 74.7 which is in the right range for umbrella instability, confirming what can be seen in the image.

III. VISUALIZATION TECHNIQUE

In order to take the image the vase was filled with cold water. Cold water was better from taking images of the umbrella instability because the India ink did not diffuse and mix into the water as quickly, this allowed for more time for the image to be taken. Once the vase was set in front of the white poster a knife was used to set the manual focus of where the images would be taken. The ink used in the image was called “Bombay India Ink” and had really nice color for distinct pictures. Once everything was set a few drops of the blue and orange India ink were simultaneously dropped into the vase and the images were captured by holding down

The lighting in the image was natural light during the day. In order to keep the glare down the white pull down blinds were pulled over the windows so the light coming through the windows would be more diffuse.

IV. PHOTOGRAPHIC TECHNIQUE

[1] Bosse, Thorsten, et al. "Numerical simulation of finite Reynolds number suspension drops settling under gravity." Physics Of Fluids 17, no. 3 (March 2005): 037101. Academic Search Premier, EBSCOhost (accessed Feb 1, 2014).
[2] "Water - Dynamic and Kinematic Viscosity." Water - Dynamic and Kinematic Viscosity. Engineering Toolbox, n.d. Web. 01 Feb 2014.

In order to capture this image a Canon EOS Rebel T1i was used with a Canon EF-S 18-55mm f/3.5-5.6 IS lens. In order to take the image the camera was set up on a tripod a foot away from the vase in order to try and focus as much as the ink as possible. The ISO was set to 400 in order to reduce any sort of grain in the image and the exposure time was set to fastest setting without getting a dark image, 1/8 of a second. The aperture was set to 4.5 which limited the depth of field but allowed for more light in the image. In this image the vase width is about 4 inches and the height is about 6 inches.

In the final editing of the image the contrast was brought up to brighten the colors of the orange and blue India ink's and the final image was cropped from 2300 x 4426 pixels to 2221x 2712 pixels.

Figure 2: Unedited Photograph

V. IMAGE ANALYSIS

This image clearly demonstrates the umbrella instability theory. The transition from the smooth streamline to bag like structures within the fluid is clear as Reynolds number increases as the drop moves to the bottom of the vase. The image could have a little bit better focus and that could be changed by the setting the aperture value higher. The next thing I would be interested in seeing would be to change the water to a think creamy substance such as heavy whipping cream and watch the ink travel through different viscous materials.

Image Assessment Form

Flow Visualization

Spring 2013

Name: Danielle Metzner

Assignment: Get Wet Date: 2/4/14

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	✓	

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		N/A	
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	N/A	
Clearly written		+	
Information is organized		+	
Good spelling and grammar		+	
Professional language (publishable)		+	
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	+	
	Field of view	+	
	Focal length	+	
	aperture	+	
	shutter speed	+	
	Frame rate, playback rate	N/A	
	ISO setting	+	
	# pixels (width X ht)	+	
	Photoshop and post-processing techniques	+	
	"before" Photoshop image	+	