Scott Legg
3/10/03
FlowVis Group Proj. 1

A Ninja Turtle's Ripple

This unique image was created in the flume using a steady flow interrupted by Donatello, a ninja turtle action figure (not a doll) to disrupt the flow near the center of the channel. The usage of the flume was the decision for the first group project. This image was specifically meant to capture the standing waves forming in front of the obstruction. The team tried various flows to increase the size and frequency of the waves; this is close to the peak fluid flow the obstruction could resist before breaking the coefficient of static friction, causing poor Donatello to fly off the heightened wooden obstacle, used as a stand. An unexpected but pleasing visual addition to this photograph is the optical magnification on the obstruction (Donatello's foot) by the working fluid, water.

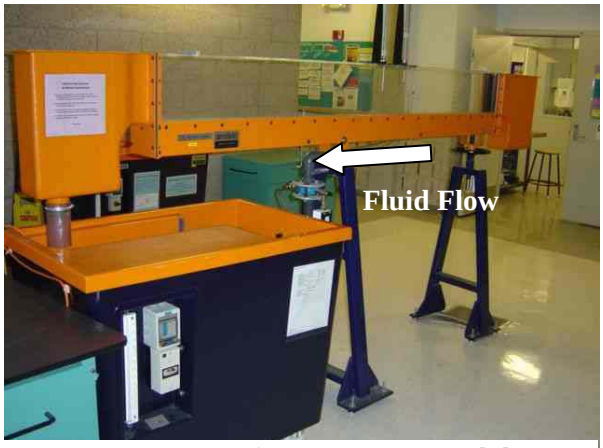

Figure 1: Armfield Water Flume [1]

For this assignment, an Armfield Water Flume (Figure 1) was utilized in order to produce a steady fluid flow that could be easily photographed. Water is pumped from right to left at a steady rate of approximately 500 mm/s (0.5 m/s). The fluid hits a partially submerged object, and flows around it. The obstruction is approximately 10 mm in diameter. The channel is approximately 76 mm wide, with about 35 mm of water running over the object. Given these dimensions, and the properties of water at 20 C, the Reynolds number is calculated using:

$$Re = \frac{\rho V D_h}{\mu}, D_h = \frac{4A}{P} \quad [2]$$

Where D_h stands for hydraulic number (to adjust for rectangular flow) with A and P standing for cross sectional area and perimeter of the wetted area, respectively. This yields approximately 2400, characterizing the fluid in a laminar state going into the obstruction, characterized by the smooth appearance. The standing ripples in front of the foot are mainly caused by the pressure force exerted by the obstruction on the fluid flow. The increase in pressure causes a slowing in fluid velocity against and creates and upwelling due to the surface tension properties of water [3]. The inertia of the slow moving water forces the faster moving water to move somewhere, creating the ups and downs. This phenomenon is not unlike a hydraulic jump often seen during rafting trips in rivers, where before an obstruction the water is moving at a supercritical speed before the object and a subcritical speed after. The waves are stationary because they are the summation of the pressure waves [4] being reflected by the sidewalls of the flumes channel. As the water moves past the obstruction, the waves begin to break apart to fill the vacuum behind Donatello's leg as well as because of friction from the sidewalls themselves.

This photograph was realized using only the flume and water, there was no need for other technique such as dye injection. Donatello was self supplied, and the flume is located downstairs in the ITLL. A composite background was hung off the far side of the flume wall to create a simple backdrop. The lighting stand from the media shack supplied light using dual Tungston-Halogen lamps, which were offset, aimed above and slightly to the left of the ninja turtle to minimize reflections from the flume sidewalls. These were approximately 1 meter away. No flash was applied.

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Camera Information:

Make: Casio Computer Company
Model: EX-Z700
F-Stop: f/4.3
ISO: Unknown
Exposure Time: 1/200 sec.
Focal Length: 6.2 mm
Dimensions: 3072x2304
Distance from Lens to Specimen: 4 inches

The field of view is approximately 100 mm tall by 130 mm in length. In Photoshop, I used the clone tool to remove a large water droplet on the near flume wall and to remove the shadow in the upper left cast by Donatello. The healing tool was then applied to both areas to smooth out the corrections. I also used the curves function to increase contrast and maximize the color differentials as well as to brighten the image overall, however this correction was very small.

This image shows how a stationary physical disturbance can affect a flow in a confined space. I really like how well the standing waves were captured and the composition of the photo; what many would call the subject isn't square in the middle. This forces more eye movement into the audience. My favorite part is the magnification of the foot, I just find it very aesthetically pleasing. The waves are shown very well, especially considering there is no surface dye to increase contrast. I do wonder if something like dying the surface would bring out the waves more, as well as how the particular shape and placement of Donatello's leg effects the flow. If his leg were more to one side, would the waves still be stationary? I am curious if instead of the obstruction being a contoured leg, if it were a perfect cylinder, how that would affect the fluid flow. I know from rafting the smoother and more perfect a shape is, the stronger the hole, so maybe a perfect cylinder would have a tighter seal around it. My intent was fully fulfilled, although I would like to try to light the right end of the picture as well as the front. To develop the idea further, I would try different shapes in the flume under the same flow conditions to better describe the ripples before the objects.

References:

1. DANIEL CAHN AND JEAN DORIOT. ARMFIELD OPEN CHANNEL FLUME OBSTACLES AND DYE INJECTION SYSTEM. Summer 2004. http://www.colorado.edu/MCEN/flowvis/course/ArmfieldFlumeandDyeSystem.pdf Accessed 3/10/2009.
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