Group Assignment #2
Flow Over Rectangle Cross Section in Flume

Photo taken 11/2/07

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The purpose of this image is to display a phenomenon that occurs when water flows over a blunt object like a dam. To show this I decided to use a flume to simulate the water flow and a special fixture to represent the dam, and impede the flow of water through the channel of the flume. As a byproduct of this flow there is also surface tension between the water and the inside of the flume. This crates a unique effect in the image which makes the water look like its twisting. It was difficult to get a good time resolved shot of this flow due to the difficulties of lighting without ruining the image or creating reflections. Once we obtained the desired lighting, the water created interesting and unique shadows inside of the image.

To create the desired flow we used an Armfield Water Flume. This apparatus consists of a pump to create the flow, a channel, a return area, and a reservoir. The water flows in from the right and flows to the return area at the left. We used plastic rectangles at the return side of the channel to raise or lower the level of water in the channel. A picture of the flume is shown below:

Fig 1: ITLL Armfield Water Flume [1]

The cross sectional dimensions of the channel are 76mm X 250mm. Inside of the flume I used the wall fixture to impede the flow. Then manipulating the flow rate and the height of the water on the return end of the wall I created the desired effect. The setup of the wall inside of the flume is shown below along with a picture of the wall fixture itself.

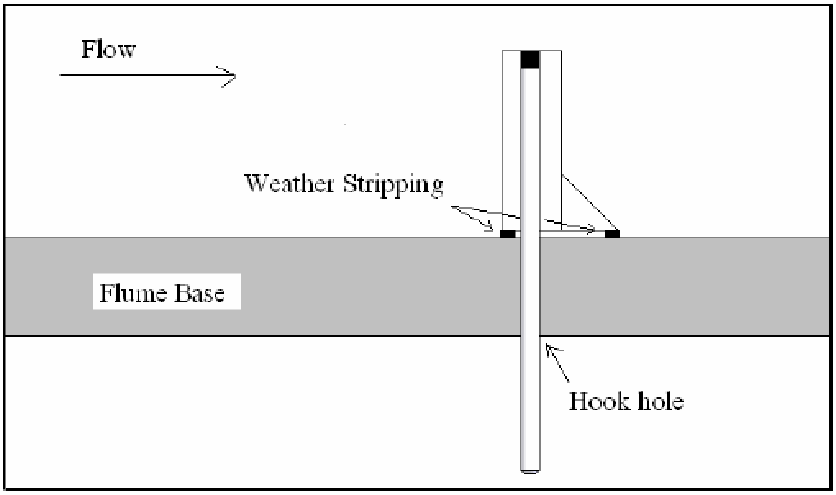

Fig. 2: Wall fixture inside flume (left). Wall fixture (right). [1]

To secure the wall inside of the flume a hook was used. The hook was inserted from the bottom of the flume into the channel. The wall was then placed inside lining up the hole in the wall with the hook's shaft. After installing the wall we ran a slow flow over it to insure the channel was not leaking.

There is a great deal of physics being shown in this image. Starting from the right you can se the laminar flow of the water as it travels over the wall fixture. We approximated the volumetric flow rate to be 0.25 L/s. Using this value along with the height the water falls I have estimated the Reynolds number of the falling water to be approximately 960. This is far below the turbulent flow Reynolds number for flow in a channel of about 3000 [2]. This laminar flow can be clearly seen by the smoothness in the flow prior to it making contact with the water again. The other aspect of the image that has interesting physics is the flow of the bubbles in the water. These air bubbles are created when the falling water traps small amounts of air and pulls it down into the water. The erratic motion of the bubbles is a result of the moving water coupled with the buoyancy of the air in the water. This creates instabilities in the water and allows the air bubbles to flow randomly in the water. Finally the water seems to almost twist while it flows over the wall fixture. This is actually an illusion created by taking a still photo of the moving flow. In reality there is surface tension between the channel wall and the water. This pulls the water up on the sides and forms a U shapes as it flows. This effect creates a very interesting effect in the image.

The only visualization technique used was the flowing of water. The detail inside the image can be seen because there are shadows created by the lighting. We could not directly light the flow due to the fact that the water was moving through the flume where both sides of the channel are made of Plexiglas. We used a piece of white Plexiglas with hooks on the top to serve as a backing for the image and to disperse the light. The Plexiglas was hung from the back side of the flume with two lights located behind it. Both of the lights were located slightly below the flume pointing up, and were located slightly right of the wall fixture. This placement along with the flowing water is what creates the unique light gradient and shadows present in the picture. We did not use the cameras flash because it created a distracting reflection in the images.

To take this photo I used a Nikon D80 digital camera. The image was saved with a pixel size of 3872 pixels high by 2592 pixels wide. The images the field of view is approximately 9in high and 6in wide. When taking the photograph the distance from the lens to the object was approximately 6in. The focal length of the lens was 50 mm. The cameras settings for the image were a shutter speed of 1/250 sec, an aperture of F/5.6, and an ISO setting of 100. After cropping the original image, there were some distracting features in the bottom right that I wanted to remove. To do this I used the healing brush tool in Photoshop. I also tried to remove the water bubbles that had splashed onto the inside of the channel using solid works, but was unable to remove them without ruining the light gradient, or interfering with the flow itself. The before and after images are shown below:

Final Image

Original Image

This image does an excellent job of showing what happens in rivers, streams, and dams when water flows over blunt objects. The water flows over the wall fixture and falls into the moving water at a lower height, pulling down air in the process and creating the bubbles. The spinning and turbulent motion of the bubbles is due to their buoyancy and the velocity of the water. This is the aspect of the image that I like the most, creating an almost surreal effect. The aspect of the image I dislike is the water spots that are on the sides of the flume outside the flow. These water spots are slightly distracting and take away from the gracefulness of the image. I wasn't able to remove these spots without ruining the light gradient in the picture. This image shows exactly what I wanted to show and is an excellent example of how one can model large scale motion and see the same type of physics. If I were to peruse this subject I would try to create two levels for the water to cascade down with a pool in the middle. This however might require a large test setup than the flume can provide.

Bibliography

1. Cahn, Daniel, and Jean Doriot. "Armfield Open Channel Flume Obstacles and Dye Injection System." Summer 2004. 5 Nov. 2007 <http://www.colorado.edu/MCEN/flowvis/course/ArmfieldFlumeandDyeSystem.pdf>.

2. Tsukahara, Takahiro, Yohji Seki, and Hiroshi Kawamura. "DNS of Turbulent Channel Flow At Low Reynolds Numbers." 5 Nov. 2007 <http://murasun.me.noda.tus.ac.jp/pub/2005/TSFP4_tsuka.pdf>.