Open Channel Flow - Flow Visualization IV3, Team Assignment 2

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INTRODUCTION

This image was taken for the second team project in the flow visualization course. I aimed to capture the beautiful open channel flow over an object with two hydraulic jumps. I originally wanted to capture a video of the flow rate increasing and decreasing, but the video was grainy due to the poor lighting in the room. As such, I opted for a still photograph of the image. Thank you to Will Dietz, Ryan Wells, and Kelsie Kerr for helping to set up the apparatus and take the image.

APPARATUS SETUP

The apparatus used to take this image was the Flume located on the bottom floor of the ITLL at the University of Colorado Boulder. A flume is an engineering structure that measures water flow through an open channel. The device has a large tank full of water and a value that controls the flow rate. The water is pumped through a tube from one side of the tank to the other and flows back through the channel. An object with two humps was placed in the flume so that the flow was 'obstructed'. A flume, similar to the one used is shown below in figure 1.

Figure 1: Flume setup with an object obstructing the flow. (1)

Additionally, the object used had a maximum height of 4.2cm a min height of 2.2 cm and a length of 22 cm and a width of 6.5 cm. The object is shown below in figure 2.

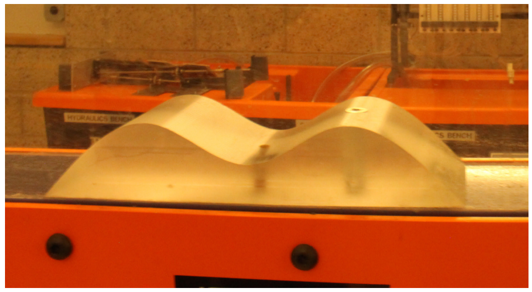

Figure 2: Object used in the Flume to capture image

FLOW PHENOMENON

As mentioned previously, the flow phenomenon observed in this photograph is open channel flow over two hydraulic jumps. As seen in the image, the flow has a bigger depth before the jumps than it does after. This illustrates that the flow accelerates as it moves over the jumps. Figure 3 below shows the fluid mechanics of a hydraulic jump. Although the object demonstrated 2 hydraulic jumps, I approximated it as one for simplicity.

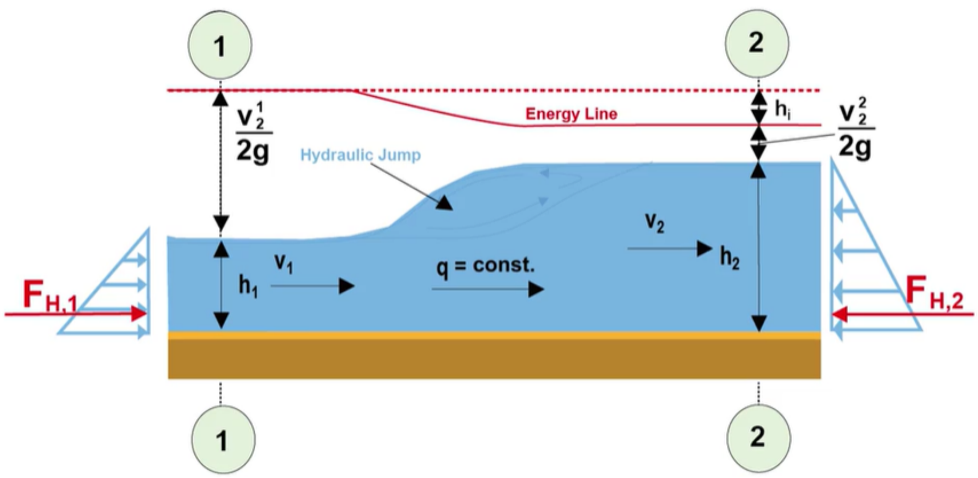

Figure 3: Diagram of hydraulic jump in a rectangular open channel (2).

While this figure shows flow the going the opposite direction the principles and equations are the same. The equations that describe the velocity of the system are

$$V_1 = \frac{Q}{A_1}, V_2 = \frac{Q}{A_2} (3).$$

Where A is the flow area calculated by height h, and depth, Q is the volumetric flow rate.. In this image te flow rate was measured at 2 $\frac{liters}{s}$ of 2000 $s\frac{cm^3}{}$. The measured heights were

$h1 = 3cm$, $h_2 = 8.5\ cm$, $A_1 = 30\ cm^2$, $A_2 = 85cm^2$. As such, the velocity before the jumps $V_2 = 23.52\ \frac{cm}{s}$ and after the jumps $V_1 = 66\ \frac{cm}{s}$.

IMAGING TECHNIQUES

A Canon EOS Rebel T7i camera with an 18-55 mm lens was used to capture this flow phenomenon. The focal length was set to 33mm, the ISO to 1600, the aperture to f/10.0, and the exposure to 1/100. I used a focal length of 33 mm because I found it to be the best length to keep everything in the frame and focus while still capturing the desired field of view. Additionally, I used the setting listed above because the lighting was less than ideal. These settings were best to slightly underexpose the image and prevent extreme noise in the image. The edited photo has a field of view of approximately 60 cm wide as approximated by the dimensions of the object and the sheets of paper on the back wall. The apparatus was positioned approximately 20 cm from the lens, and the focal distance was 41 cm. The lighting used was fluorescent lighting sourced by the ITLL building located that hung about 5 feet from the top of the flume This image's editing was done using darktable. I cropped the photo to the desired size, added an S-curve, and denoise the image with denoise (profiled). Additionally, I set the color correction to blue; I set the contrast to +0.12, the brightness to +0.05, and the saturation to +0.0. Finally. I set the shadows to -6.23, the highlights to -50.0, and the white point adjustment to +10.0. The original and edited images can be seen below in figure 5.

Original: 6016 x 4014 pixels

Edited: 6016 x 2696 pixels

Figure 5: The original image and the edited image; image size is displayed underneath each in pixels.

CONCLUSION

The angle of this image shows how the flow rate decreases as it encounters the image. I enjoy the angle and the 3D aspect of the image. If I were to retake this image. I would bring better lighting equipment so the glare and reflections in the image could be reduced. Additionally, I would use a larger sheet of paper to cover the entire back wall of the flume rather than part of it.

Bibliography

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