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MCEN 4228 – Flow Visualization
Group Project 1- Group Alpha

Rectangular Weir in a Water Flume

This was the first group project for Group Alpha, working on the flume. The original intent was to visualize water flow over basic objects and weirs in the contained environment of the flume in order to observe any interesting phenomena. The group had little prior experience with the flume so the work was primarily experimental – simply attempting different methods until something interesting occurred. The final image was water flowing over a rectangular wooden weir. A weir is a small overflow dam commonly used to raise the level of rivers or streams (wiki. pp. 1). Figure 1 shows how the weir causes water on the leading edge to raise proportional to the weir's height and shape. The height of the water above the weir is proportional to the water's velocity. Even more interesting is the formation of an air pocket on the trailing edge of the weir having the same geometry as the flowing water. The final image highlights this phenomenon in conjunction with the flowing water over the weir.

The flow apparatus is the open-channel flume located in the ITLL at CU. A schematic of the setup can be seen in Figure 1 below. It consists of a reservoir-pump system that pumps water from a reservoir down a long (~8 feet), narrow (~4 inches) glass channel and returns it back to the reservoir. It simply circulates water down the channel so that flow can be easily observed. The weir is a 12in. long, 3in. high block of wood with the same width as that of the channel. It has a notch cut into the base that allows it to be secured to the bottom of the flume channel by a hook so that the flow of water does not move it. The hook is located approximately 1.5 feet from the incoming flow of water. The water's velocity was approximately 3-5 ft/sec. This was estimated by observing the time it took for a small plastic ball to travel the length of the flume. The height of the flow was 3-4 in. above the top of the weir at its highest and 1 in. from the base at it's lowest. This gives a Reynolds number ($\mathrm{Re} = \frac{\vec{v} r_H}{\nu}$ where $r_H = \frac{Area}{Perimiter}$) of approximately 40,000 indicating turbulent flow (Smits, p. 270). The basic flow appears to be relatively laminar as the water flowed smoothly down the flume and around the weir. However, the inclusion of dye would most likely indicate turbulence at the leading and trailing edges of the weir.

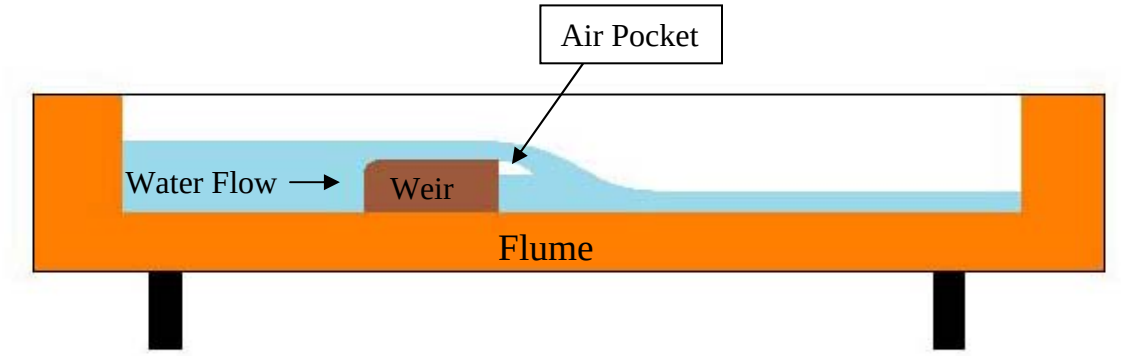

Figure 1: Flume and Weir Setup

The visualization technique was simply the water in the flume flowing over the weir. The image is more about the flow of water as a whole instead of the internal movements within the water. A piece of white acrylic was hung on one side of the flume directly behind the weir to give a backdrop for the image. Two medium sized rectangular halogen lights were used to light the image. They were approximately two feet from the flume and directly perpendicular to the motion. The entire apparatus was contained indoors with no outside forces acing on it and with little to know sunlight. The lights were effective in illuminating the setup but considerable glare off the glass walls was very present and difficult to avoid completely.

The camera was positioned looking down the weir (water moving away from the camera) at an angle of about 45 degrees to the direction of motion. The distance from camera to the glass walls of the flume was roughly 6 inches. The camera specs for the image are given below

- Camera Type: Olympus FE-340, 8.0 megapixel, 5x optical zoom
- Lens: AF ZOOM 6.3 – 31.5mm, 1:3.5-5.6
- Field of View: Approx 8 inches high x 18 inches wide
- Shutter Speed: 1/100 sec
- Focal length: 6.3 mm
- F stop: f/3.5
- Aperture: 3.62 mm
- ISO: 64
- Resolution: from camera = 266 x 266, final image = 10551 x 5376
- No Flash
- No Zoom

The final image was cropped to leave only the fluid flow over the tail end of the weir. Photoshop was used most noticeably to convert the image to black and white. The calculations adjustment was used, but with inverted red and green channels to give the high contrast, almost silvery tone in the final image. Care was taken to avoid washout and removing information present in the original. Areas that are completely black were so in the original image and were not a product of color washout. Additionally the healing brush and clone stamp tool were used to remove unsightly droplets of water on the glass not related to the imaged flow. This may seem like a lot but I feel it adds a great artistic quality while still highlighting the wonderful physics.

The image reveals a simple but quite remarkable fluid phenomenon. I really enjoy that the top and underside of the free surface of the flow is clearly visible as it travels over the weir. The air pocket that forms at the base of the weir is definitely the most astounding aspect I feel. It was something that all of us in the group did not know would form and I am still not entirely sure what it is specifically called. I do like the final transformation into black and white although some may disagree. In developing this idea further, the inclusion of some sort of dye could be very interesting in order to gain information on the internal aspects of the fluid flow compared to the flow as a whole. Also better care with, or inclusion of additional lighting could really help with some of the glare we encountered off the glass walls. Personally, I really enjoyed the observations we made in working with the flume, and I am rather pleased with the final image.

References:

Weir. Wikipedia entry obtained 10 March 2009. http://en.wikipedia.org/wiki/Weir

Smits, Alexander J. *A Physical Introduction to Fluid Mechanics*. Princeton University Department of Mechanical Engineering. John Wiley & Sons, 2000.