Hydrostatic Forces Varying with Depth

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MCEN 4228: Flow Visualization
Image Assignment 1
25 September 2007

"Hydrostatic Forces Varying with Depth" is a visual depiction of the forces due to pressure that water molecules feel through the use of fluid flows. The still picture shows three streams of water flowing from three holes in a bottle. Each stream is traveling a different distance horizontally, an attribute of the streams that is indicative to the placement of the holes in the bottle.

To produce the image a plastic bottle was cut such that three equally spaced holes were in the bottom, aligned vertically. In order to create a greater amount of pressure head in the flow, a tall bottle was used. The holes in the bottle were covered while water filled the bottle to the top. All three holes were then released at once, allowing three streams of water to flow from the bottle and into the catch basin below (Fig. 1).

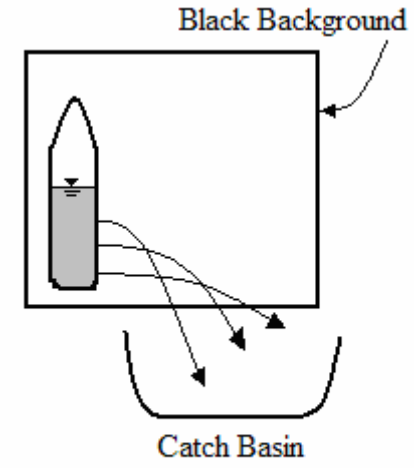

Figure 1: Set-Up

The lowest stream is traveling the farthest horizontal distance because there is more hydrostatic pressure from above forcing the stream through the opening. Conversely, the top hole is traveling the shortest horizontal distance because there is less hydrostatic force from above, relative to the holes below it. For this particular photo, the holes were .5 inches in diameter, 1 inch apart vertically, and at the time of the photo the water level was ¾ inch above the top hole. The total flow rate of fluid out of the bottle was .045 gal/s (measured experimentally).

The hydrostatic force is a result of the weight of water above the point. This force varies linearly with depth, and is also known as pressure. Because the pressure is a result of the weight of the fluid, the line in Figure 2 that represents the magnitude of the

pressure at each height in the bottle, can be written as:

$$p = \gamma \cdot h,$$

where p is pressure (lb/ft^2), γ is the specific weight of the fluid (lb/ft^3), and h is the height above the point of interest to the fluid surface (ft). One property of pressure in a fluid is that it acts equally in all directions. Because of this, where the pressure is greater, i.e. towards the bottom of the bottle, and a hole is placed the water flowing from it will have higher velocity than a hole placed in the same bottle at a higher location.

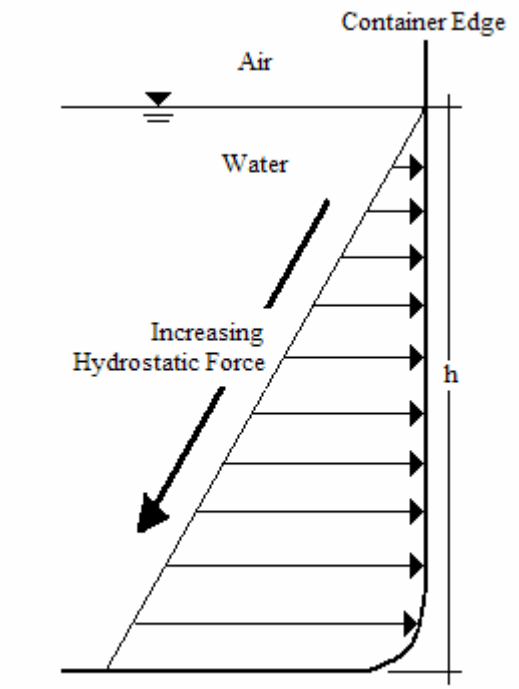

Figure 2: Hydrostatic Force Diagram

The average speed of the water in the streams is estimated at 5.0 ft/s. Using this, the Reynolds number of the flow is approximately 1.5 x 10^7, indicating that the flow is turbulent. The velocity of the flow was also used to estimate the spatial resolution of the image, found to be 20 pixels/element. This was found by estimating that the flow moved a tenth of an inch during the photo.

In order to illustrate the phenomena, tap water against a black cloth was used. The flow was turbulent enough such that light scattered well off of the stream of water and the set up could easily be seen without the help of any marking. Utilizing the stock flash from the camera, the stream could clearly be seen without needing to use additional light sources.

The final digital photo was edited using PhotoShop; the original photo can be seen in the electronic copy of files associated with this report. The original photo was taken with a black felt background, therefore in the picture there is a shadow from the

stream. The background also does not come out as deep black in the photo because the felt does not absorb light from the flash well and comes out as gray. As a result of this, the final photo was edited to make the background deep black to bring out the light being reflected by the streams of water. To do this, the color of the original shadowed areas was brought out into the rest of the background using the mask tools and the clone stamp tool. This was the only editing done in PhotoShop. A full listing of the camera settings is listed in Table 1.

Table 1: Photo Parameters		
Medium	Digital Photograph	
Camera	Nikon D40x	
Lens	Nikon 18-200 mm F/3.5-5.6 VR	
Resolution	3872 x 2592	pixels
Focal Length	150	mm
Shutter Speed	1/60	sec
Aperture	f/5.6	
ISO	200	
Fied of View	12 x 8	in

The aperture is set as low as possible so that the shutter speed could be quick enough to catch the flow with minimal blur. The photo was taken approximately 4’-6” from the flow.

The image is a good representation of a simple aspect of fluid mechanics; however it lacks a great artistic component. It is easy to determine what is happening with the flow as the photo came out clear as it is focused and the lighting came out quite nicely after editing. If one aspect of this set up were to be changed, the holes could be staggered horizontally as well as vertically in order to get streams of water that did not collide with each other. This might better illustrate the flow, however the intent of the image was still realized despite the streams flowing together in the final submittal.