Team Project #3: Swirly Pearl

Millie Blackstun 4/29/2014

Project Objective

The third team project was ripe with false hopes and disappointing failures. I originally did a series of smoke and fire pictures with Vick Selvaraja and Amanda Kennedy. We captured some interesting phenomena, but I was disappointed in the lighting and background we had available. So I agreed to meet Jason Brownstein a few days later, and we played around with the Pearl Swirl Tank. I had originally imagined creating a von Karman Vortex Street, but was mildly unsuccessful in controlling the flow. As we experimented with the PVC channel, we began sending oscillating waves up and down its 4ft. length. The wave propagation was generating some classic turbulent boundary layer, laminar in the middle, Poiseuille flow. So I went back to basics and used the Pearl Swirl and wave propagation to illustrate boundary layers forming on a fluid with a free stream velocity. Obviously, the PVC channel had a finite length, and gravity provided the "pressure gradient" to drive the Poiseuille flow. But it certainly revealed some interesting turbulent boundary layer behavior and smooth laminar flow towards the center.

Experimental Apparatus and Flow Phenomenon

The experimental apparatus is laughably simple. At the beginning of the semester, as part of a community service project, I glued end caps onto a 4ft. black PVC pipe and sawed it in half, hotdog style. I took a channel back out to be used yet again for a flow visualization experiment. Approximately 2 Tablespoons of Steve Spangler's Pearl Swirl was mixed with 1 gallon of warm water and mixed in the PVC channel. Supplemental Pearl Swirl was added by the droplet, as needed, when it settled out. Two prefabricated stands allowed the round channel to rest on the table, as can be seen in Figure 1. One end of the channel was tipped upwards to generate the oscillating waves from one end of the channel to the other. Halogen lamps were used to add luminosity to the Pearl Swirl.

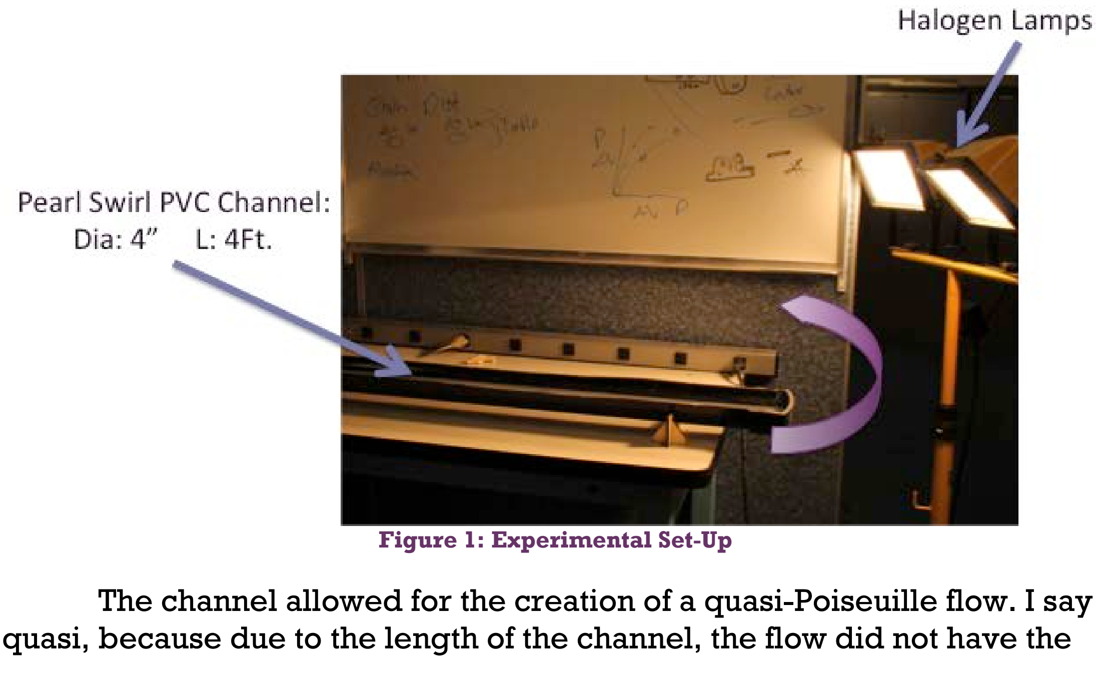

Figure 1: Experimental Set-Up

The channel allowed for the creation of a quasi-Poiseuille flow. I say quasi, because due to the length of the channel, the flow did not have the opportunity to become truly fully developed. However, it was long enough to visualize a boundary layer and free stream laminar flow in the center. The boundary layer forms, in essence, due to the no-slip condition. The molecules of fluid stick to the wall of the channel. Molecules right above (or in the this case to the side) the stagnant layer collide with those molecules sticking to the wall. The next layer collides with the molecules underneath it, so on and so forth. But the farther one moves away from the wall, the fewer collisions occur as a result of the wall. This creates the "boundary layer."

Boundary layers can be either laminar or turbulent, depending on the Reynold's number of the bulk flow. (Benson) The boundary layer in my image is clearly turbulent as characterized by the unsteady, swirling flows within the boundary layer. Towards the center, the flow reaches its laminar free stream velocity, as depicted by the milky, smooth Pearl Swirl. It is not the perfect Poiseuille flow, but it demonstrates the general concept.

Flow Visualization Technique

Pearl Swirl is a fun and aesthetic instrument for visualizing shear flows. Although its actual composition is kept a trade secret by Steve Spangler, Pearl Swirl is a simply a rheoscopic fluid. (Spangler) A similar substance may be ground up fish scales, which is also sometimes used for flow visualization. Rheoscopic means that the fluid consists of microscopic particles suspended throughout it, which align with the flow velocity and the local shear to create high-contrast depictions of flow phenomena. (Barth und Burns)

By directing halogen lights onto the Pearl Swirl, it appeared more luminescent. The halogen lights did give it a yellowish-red tint, which I altered, as described in the Photographic Technique. The channel containing the Pearl Swirl liquid was rocked back and forth generating an oscillating wave. Had the channel been infinitely long, we may have had true Poiseuille flow, with well-defined boundary layers and a fully developed free stream velocity at the center. However the channel was finite so we had to be quick in capturing pictures, as eventually the changes in flow direction disturbed the previously formed boundary layers. The waves created turbulent boundary layers, which was visualized through the Pearl Swirl. Once the wave had propagated far enough down the channel, the photo was taken.

Photographic Technique

Approximate numbers for capturing the image are given in Table 1.

Field of View	30”
Distance from Object to Lens	24”
Lens Focal Length	40mm
Type of Camera	Canon T3 DSLR
Final Picture Size	2268 × 4330 pixels
Exposure	Shutter Speed: 1/64th second Aperture: 9.0 ISO: 125
Post-Editing	Perspective Cropped, and Brightened Turned up saturation of Magenta, Cyan and Blue. Turned down saturation of Yellow and Red. Increased contrast

Table 1: Photographic Specs

The shutter speed didn’t need to be too fast, but I didn’t want motion blur in the eddies. The f-stop allowed for a decent sized depth of field, so as to see the boundary layer development along most of the channel. The ISO was turned down low due to the bright halogen lamps and Pearl Swirl reflectivity. The cropped original is given in Figure 2 and rotated to save space. I didn’t like the orange tinge to the image, and I wanted the final photo to seem spectral, hence the turning up of Magentas and Cyans and eliminating the reds and yellows. I also darkened the edges so that the viewer cannot tell that they are looking at a PVC channel, but instead are wondering what the apparition may be.

Figure 2: Original Cropped Image

Results

Without truly knowing what I wanted to accomplish with the Pearl Swirl, I am satisfied with my image. However, if I could do it all over again, I would do several things differently. First, I would try harder to get a straightened image. I was able to perspective crop it in Photoshop, but I feel some of the definition was lost. Second, I don't think the fluid had enough time to settle between oscillation trials, or else I allowed too many oscillations before I took my picture. The boundary layers having to switch back on themselves made the boundary layer less defined. Third, I would generate the waves slower in an effort to get a laminar boundary layer. Jason and I played around with trying to get a laminar boundary layer, but without much success. I think that if we had a more controlled system, bulk laminar flow could have been achieved. But all in all, I am pleased with the mysterious nature of my final image. I like being able to give feeling and a mood to fluid flow.

Works Cited

Barth, William L. and Christopher A. Burns. fooberman.com. 29 4 2014 <http://www.fooberman.com/assets/publications/barth_07.pdf>.

Benson, Tom. NASA and the Glenn Research Center. 29 4 2014 <http://www.grc.nasa.gov/WWW/k-12/VirtualAero/BottleRocket/airplane/boundlay.html>.

Spangler, Steve. Pearl Swirl Rheoscopic Concentrate. 29 04 2014 <http://www.stevespanglerscience.com/pearl-swirl-rheoscopic-concentrate.html>.