Team Project 3: Fishbone Structure

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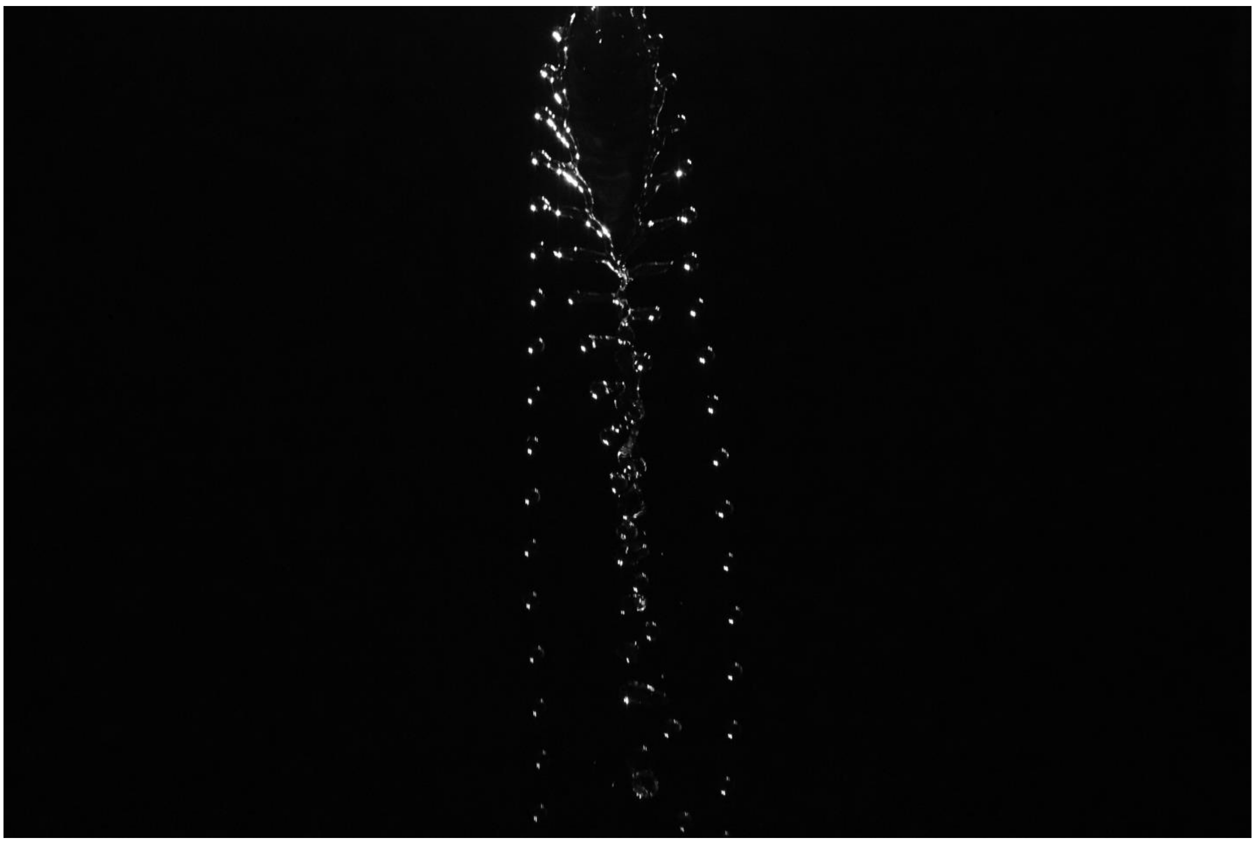

Figure 1: Fishbone Structure Formed by Two Colliding Jets

The photo in figure 1 depicts a Fishbone Structure that has been formed by the collision of two laminar jets of viscous fluid. These fishbone structures are a result of the Plateau-Rayleigh instability (Bush). The viscous fluid used to photograph this photo was a mixture of 50% tap water and 50% pure glycerin. The fluid jets are oriented such that one is going toward the plane of the structure, and the other is coming from behind the plane of the structure. To the naked eye, this phenomenon simply looks like a messy blur, but with the use of high speed photography, such structures can be captured and observed. This photo was taken using backlighting: a 700 lumen and a 1200 lumen bicycle lights. A Nikon D3300 camera was used, with a 55-200 mm lens, focused at 68mm, with both a Lens+2 macro filter and an ambient light hood, mounted on a tripod. The shutter speed was 1/4000 seconds (the limitation of the camera), an aperture of f/6.3, and an ISO of 6400 were used.

In order to capture this image, a special setup had to be made. After a stop to McGuckins, sacrificing of one of my Tupperware containers, a trip to the bike shop, and a little bit of time drilling and assembling, I had the main component to the apparatus, as seen in figures 2 & 3. The tubes that were the outlets of the container were 3 millimeters in diameter, and the container is 0.65 liters in size. A tubeless bicycle valve was attached to the container to enable the team to pressurize the container. The seal on the Tupperware container ordinarily could only handle a couple of pumps from the bike pump, however when Marco Gardi, one of the group members applied a force to the top of the container it could handle much more pressure, enabling the team to explore different fluid flow shapes.

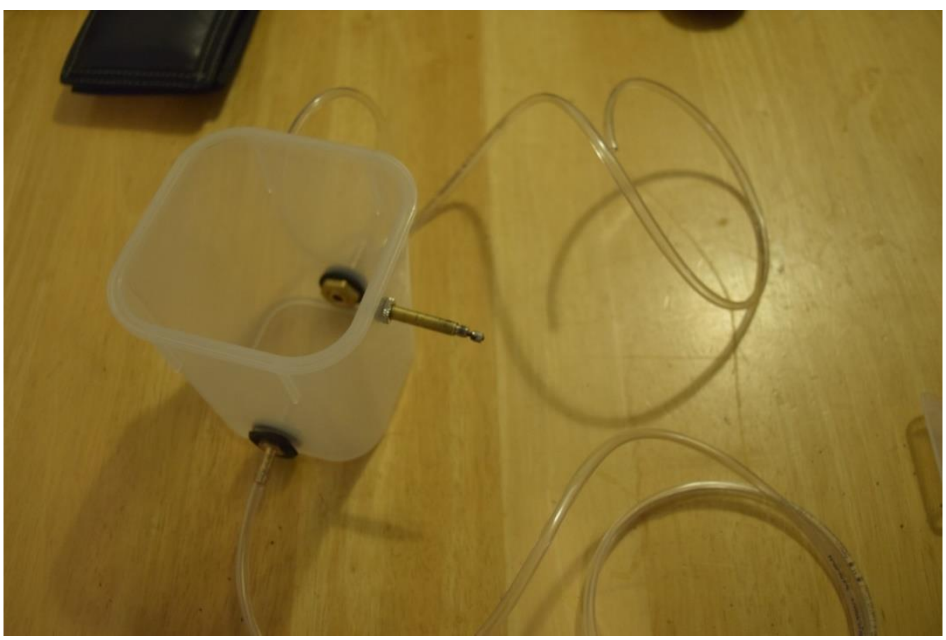

Figure 2: Inside of the modified Tupperware container

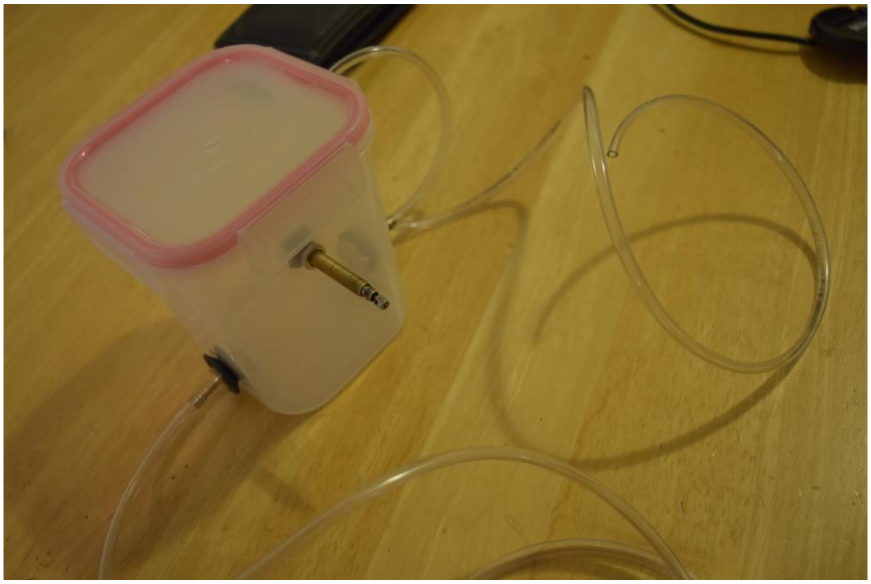

Figure 3: Tupperware container with the lid secured

During the actual photoshoot, I operated the camera and all of its attachments and settings, as well as the lighting, James Julian held the tubes at roughly a 90 degree angle from each other, symmetric about the direction of gravity, Marco Gardi applied pressure to the Tupperware container, as well as even wearing a bicycle helmet with the 1200 lumen light mounted on it at one point, and Zack Cymanski operated the bicycle pump to pressurize the container. While all members of the group were essential to the photoshoot, future iterations of this project could implement props to eliminate the need for so many people, such as an apparatus to hold the outlet tubes.

Figure 4: A fluid chain formed at low fluid velocities

When the viscous streams were at low velocities, the collision structure would form a fluid chain, as seen in figure 4. These fluid chains would grow in size until the fishbone structure would form, as seen in the juxtaposition of figures 5 and 6. It is interesting to note that there was a need for a much higher speed when the fishbone structures formed, likely because the edges of the fluid chain were smooth, and there were no distinct moving particles that needed to be captured, while the overall structure stayed relatively stable and stationary. It could not be observed from our photoshoot, however from online simulations of this fluid flow, the fishbone structures act as a wave, propagating downward from the rim of the sheet of fluid, converging at the tip of the sheet and spreading out again from there, all the while moving downward with gravity. As the fluid speed increased from here, the fluid forming the sheet closest to the point of collision would begin to form a ripple, as seen in figure 7.

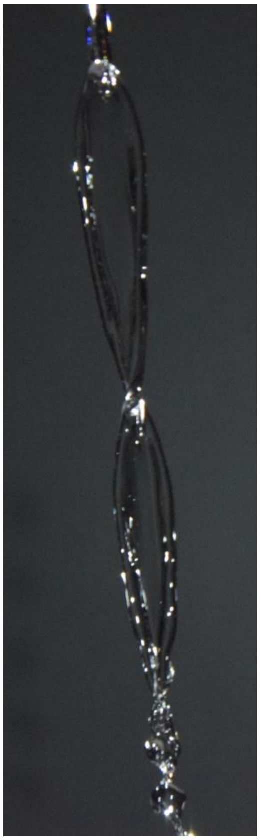

Figure 5: Fluid chain on the brink of becoming a fishbone structure

Figure 6: The beginning of a fishbone structure being formed

Figure 7: A clear representation of an oscillation in the sheet of fluid

Given the series of compromises in the camera setup with the shutter speed and lens and filter choice to get a clear shot that was reasonable for the space provided, some of the best flows were captured just slightly out of the depth of field of the camera. That being mentioned, they are still worth showing in this report for their overall shape. These are seen in the following figures:

Figures 8 & 9: Notable structures that were slightly out of focus

Even at 1/4000 seconds shutter speed, there was small amount of motion blur visible when the image is zoomed into. Perhaps, in the future, the image could be captured using a high speed flash to shorten exposure time a little bit more. A more capable camera could be used, as well as better lighting. It would be interesting to see this kind of flow phenomenon through a high speed camera, such as a Phantom video camera. More experimentation with lighting angles and fluid composition could also help; some of the team's motivation images used a fluid with a lower viscosity and more delicate ribs in the fishbone structure.

Works Cited

Bush, John W M. Hasha, Alexander E. "On the Collision of Laminar Jets: Fluid Chains and Fishbones." Journal of Fluid Mechanics. July, 2004.