Team Second - Laminar Flow

Matthew Sherman
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https://www.youtube.com/watch?v=v-VmXXyhjV8

As part of the second assignment for this flow visualization class, I wanted to demonstrate laminar flow. Going into this project, but knew it was possible to show laminar flow in mini experiments. I also wanted to answer some questions about how the pressure as well as hole size affected the laminar flow. The overall goal was to create a phenomenon I know exists and use it to learn more about how external variables affect the speed of the flow or other factors. In the end, I chose the video which showed laminar flow the best for my video.

Laminar flow can be modeled using a combination of the Navier-Stokes, Conservation of Mass, and Conservation of Energy equations to model laminar flow. One of the most interesting phenomenons I discovered was the existence of a phenomenon I later discovered to be Boundary-Layer Oscillations in the laminar flow.

This is caused by the differing speeds of the water entering the flow. As shown in the image below, as the flow goes through the open hole, it is moving towards the opposite side, but then the surface tension of the water pulls it back towards center creating a flat profile in the opposite direction. This repeats quickly as it harmonically oscillates. (Kamholz)

The following graph shows an additional aspect involving a relationship between pressure and these Boundary-Layer Oscillations. In my experiments, I tried to squeeze the balloon to increase the pressure hoping it would make the flow more interesting, but when I did this, the oscillations decreased which matches this data shown below which shows that the largest and smoothest oscillations would occur and as the pressure increases the oscillations would slowly disappear (Schubauer and Skramstad 72).

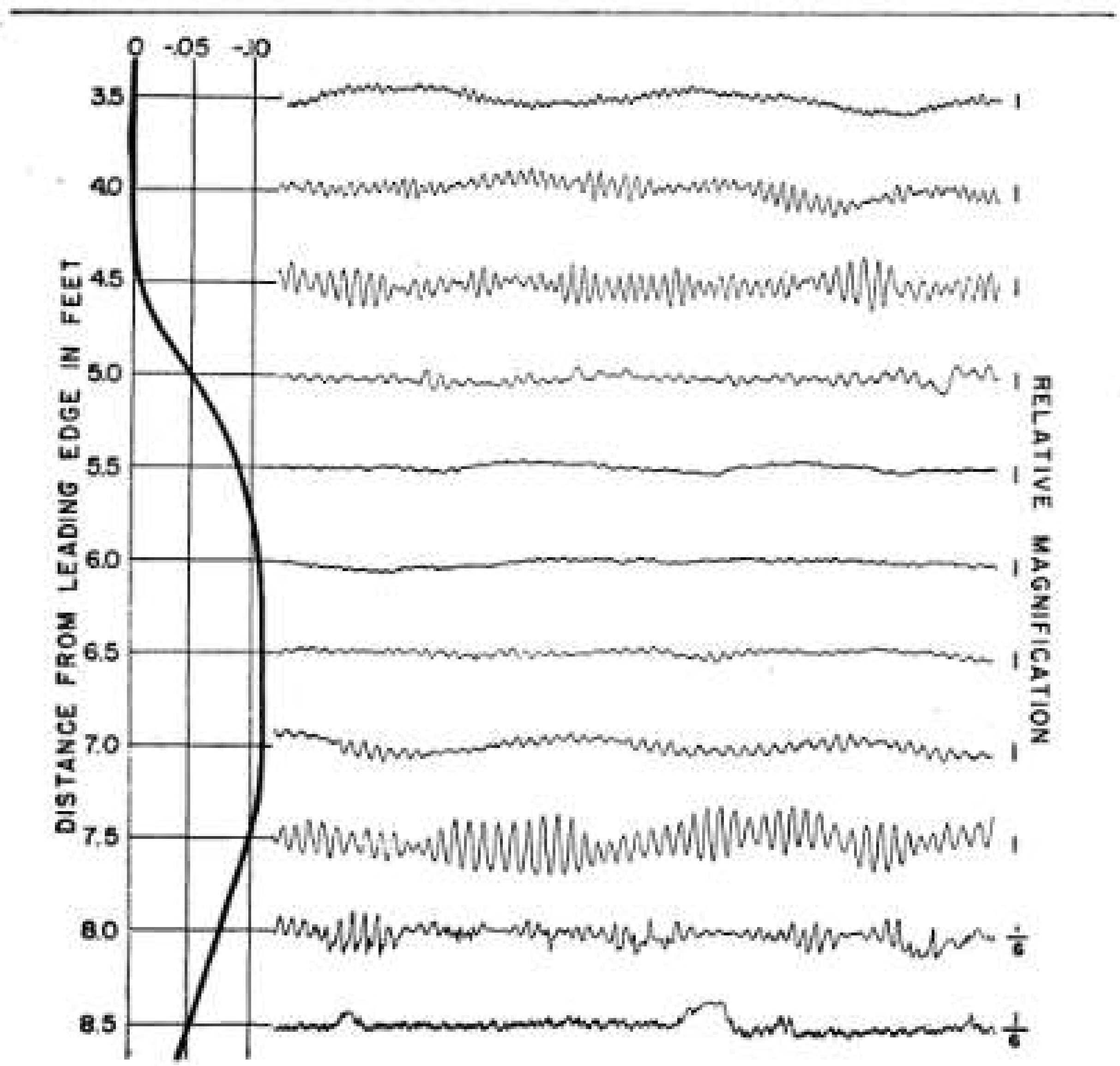
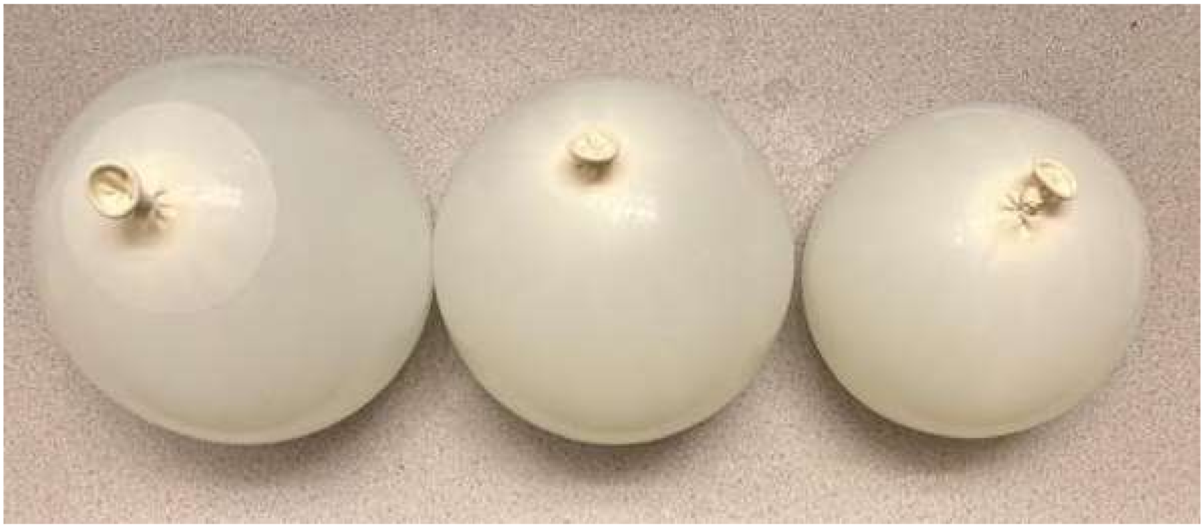


Fig. 6. Effect of falling and rising pressure on laminar boundary-layer oscillations. Scale at upper left is ratio of pressure change to free-stream dynamic pressure. Distance from surface = 0.021 in.; U_0 = 95 ft. per sec.; time interval between dots = $^1/_{30}$ sec.

To create this experiment, I first filled 3 balloons of different sizes with water and used electrical tape to create boxes on the balloon which would allow me to pop a hole in the balloon without popping the entire balloon. I then setup my camera and popped the balloon while holding it in place. The hole sizes had 3 different types: The smallest balloon was square but small (0.4’ x 0.4”), the middle balloon was square but large (0.75” x 0.75”) and the largest balloon was rectangular (0.75” x 0.2”). For the small square one, I also squeezed the balloon lightly to see how the increased pressure would affect the flow. After all 3 tests, each balloon successfully created laminar flow but the rectangular cutout balloon showed the flow the best so I chose a photo from this run. I used a flood light set to 50% power set at a downward angle of 10 degrees about 5 feet from the experiment.



Instead of taking a bunch of photos and hoping one was good, I took a video and chose the best image from it. The video was taken using a Canon EOS R100 with the following settings: Frame Rate (60fps),Shutter Speed (1/160), Aperture Value (F6.3), ISO speed (ISO800), Exposure (1.4) and a Lens Focal Length (35mm).The frame rate is standard and didn’t need to be changed, because the flow was not moving that quickly. The shutter speed was set to make sure it was fast enough to capture the whole image. The aperture and ISO speed were set to allow a lot of light in and see the reflections of the light off the water. The photo was taken from about 4.5 feet away from the flow with the frame size being around 15” x 10”.

This experiment was designed to show laminar flow and while it did succeed in that, it also showed a new unexpected phenomenon. I really liked the fluid flow because it showed theoretical fluid dynamics principles in real life. I believe this was a good way of creating the phenomenon, but due to the limited capacity of the balloon, the flow could only last a certain amount of time. Further research and development of this idea would involve creating a way to create this laminar flow in a way that is the same speed of flow the entire time. Due to the fact that the balloon has less pressure the smaller it gets, the flow speed and length was changing constantly which could be fixed just like the limited time with a different experiment setup.

Work Cited

Kamholz, Andrew Evan et al.
Biophysical Journal, Volume 80, Issue 1, 155 - 160

Schubauer, G. B., and H. K. Skramstad. "Laminar Boundary-Layer Oscillations and Stability of Laminar Flow." Journal of the Aeronautical Sciences, vol. 14, no. 2, 1947, pp. 69-78.