Tyler L’Hotta

Dron Das Purkayastha

John Smith

Dr. Jean Hertzberg

Flow Visualization 5151-002

6 November 2024

Team Second | Velocity Stacks

The internal fluid flows of a vehicle intake are difficult to comprehend and are often unintuitive. In this project, I aimed to create a two-dimensional approximation of the plenum used on the CU Boulder Racing Team competition vehicle, and visualize the alternating flows produced by the vacuum pulses of an internal combustion engine. The area of highest interest for this report regards the flow around the runners and velocity stacks.

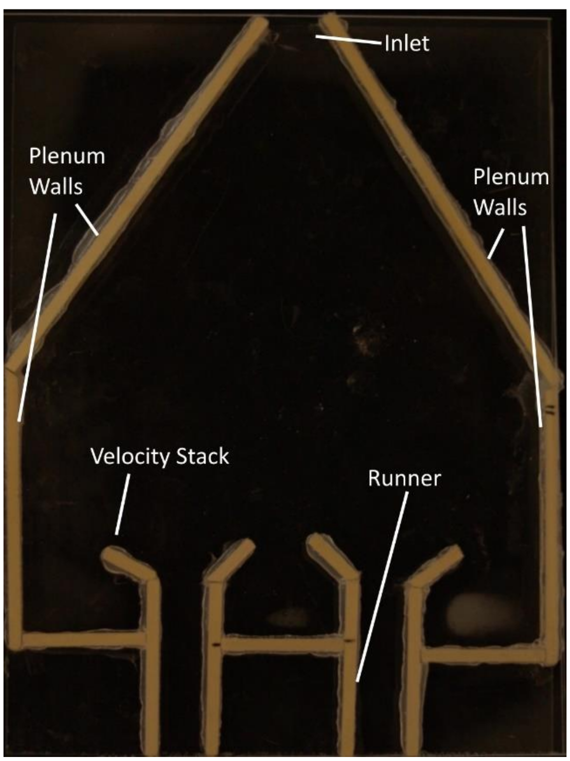

Figure 1: View of scene from camera with descriptions of setup

Figure 2: View of scale of setup

The flow apparatus is comprised of 3/16”x ½” wood furring strips laminated between 3/32” acrylic sheets, 9”x 12”. A seal was made between all components with quick setting silicon. The plenum is 10 inches tall with a 7/8” opening at the top. The runners are 2 ¾” long and 7/8” wide. The velocity stacks are 1” long at a 45-degree angle from the runner. The fog used for visualization is produced by submerging 500 grams of dry ice into three liters of 80-degree Celsius water; in this experiment the dry ice and water was placed into a laundry detergent bottle, and the valve was used to release the carbon dioxide and water vapor. The flow apparatus was placed against a black sweatshirt as a background. John Smith introduced fog from the left of the apparatus, and I utilized a handheld vacuum to drive the flow into the runners. The vacuum was then quickly alternated back and forth at a rate of one alternation every 1.5 seconds. Dron Das Purkayastha was then able to record the shot on his camera.

Characterizing the flow, I believe that the most interesting area occurs at the ends of the velocity stacks, where the viewer can see pulses of fog. I believe that these pulses can be most readily attributed to the Kelvin-Helmholtz Instability in which there is velocity shear in a continuous fluid. I believe that the sharp edges of the velocity stacks tear the flow and create separation and the visualized roll up of the flow (Matsuoka 2014). The secondary characteristic, which may also be a part of the Kelvin-Helmholtz Instability is the production of mushroom-cloudesque vortices erupting from the top of the velocity stacks. To better understand the flow, the Reynolds number was computed with the density of fog, the viscosity of air and the speed of the flow being one inch over three frames:

$$Re = \frac{\rho u L}{\mu} = \frac{0.0005 \frac{kg}{m^3} * 0.508 \frac{m}{s} * 0.0254m}{1.758 * 10^{-5}\ Pa \cdot s} = .369$$

The low Reynolds number indicates that in the runners the flow is very unlikely to be turbulent, and the instability is almost strictly shear driven.

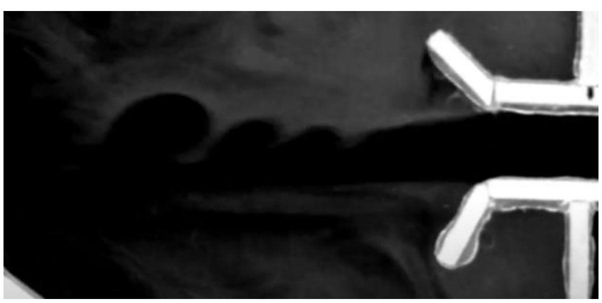

Figure 3: Traditional Kelvin-Helmholtz instability

Figure 4: “Mushroom Cloud” vortex

The only controlled aspects of the visualization were the vacuum alternation speed, the lighting and the background. We selected a dark background to enhance the visibility of the fog and diffused the light from the nearest window and overhead lights to negate glare on the acrylic. The scene was recorded just after mid-day to give the best lighting through the window near our testing location. The window was western facing, 2 meters by 4 meters, approximately 2 meters from the testing location.

The raw video was shot at 1920x1080 at 60 frames per second on a Canon M50 Mark 1. The quality was set to optimize visual fidelity and high frame rate to capture the faster details of the flow with better clarity. Dron utilized a Canon ef 50mm 1.8 prime lens with the ISO set to 100 and the shutter set to 1/125. The shutter was established to be about double the framerate and the ISO was used to set exposure. The field of view was approximately 9”x16”. The framing was set such that the heigh encompassed the entire flow apparatus, and the width was cropped in post processing to match the width of the flow apparatus. In editing the video, I maximized my exposure and contrast while dropping the saturation the get the greatest visual effect from the fog. In my editing I focused primarily on the flow effects around the velocity stacks, while still giving context to the whole flow. I played a melancholy piece called Crystal Peaks and set the clips to transition at lows in the music, giving the video a moody aura to match the dramatic black and white visuals.

Before	After
	

I am rather surprised with the success of the visualization in post processing. The raw video was rather uninteresting, and the colorization made it difficult to determine any meaningful information with the naked eye. I am happy with the coloring and the contrast between the flow and the background. I intend on carrying this experiment further with more accurate models of a vehicle intake and attempting to better control the light in pursuit of achieving more detail of the fog. I fulfilled my original goals and outperformed my initial expectations, and am now driven to go further with this research.

References

Chihiro Matsuoka (2014) Kelvin-Helmholtz Instability and Roll-up. Scholarpedia, 9(3):11821.

de Oliveira, W., Hanriot, S., and Queiroz, J., "Analysis of Pulsating Phenomena in the Intake Manifold of an Internal Combustion Engine Using the Acoustic Theory," SAE Technical Paper 2020-36-0082, 2021