Tyler L'Hotta

Dron Das Purkayastha

John Smith

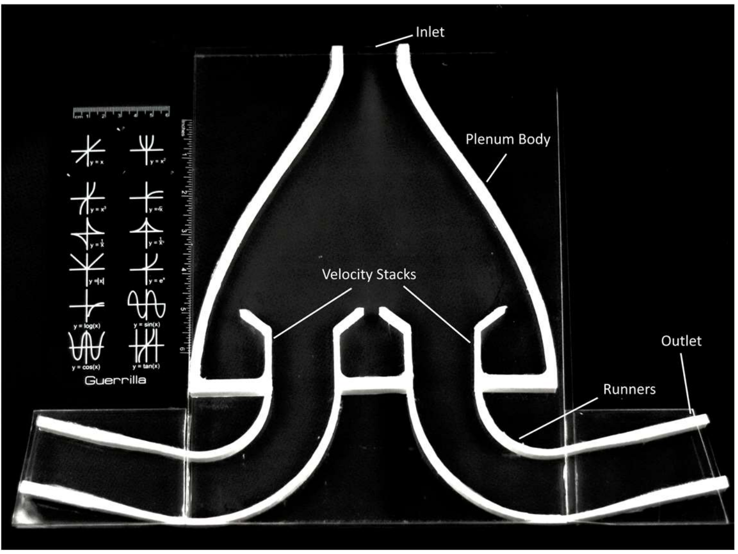
Dr. Jean Hertzberg

Flow Visualization 5151-002

4 December 2024

Team Third | Ebb and Flow

Pursuing a refined model from the team second assignment, I aimed to create an exact two-dimensional replica of the air intake plenum used on the CU Boulder Racing Team FSAE competition vehicle. The flows of the previous project proved interesting; in this project a greater emphasis was placed on analyzing the flow intrinsic to the geometry of the intake rather than general fluid flow phenomena.



s

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

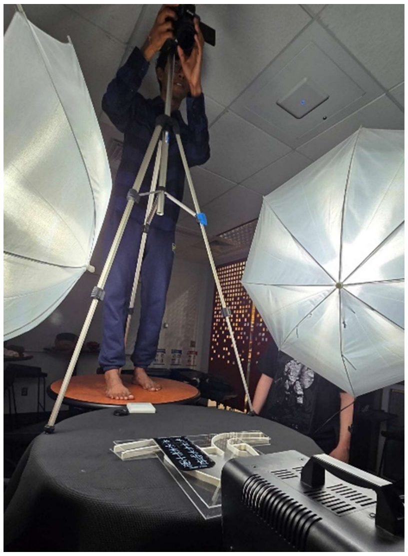


Figure 2: View of setup

The updated flow apparatus is comprised of ½" tall 3D printed walls laminated between 3/32" acrylic sheets. A seal was made between all components with quick setting silicon. The plenum is 8 1/8" inches tall at its widest point, with a 1 3/8" opening at the top. The runners are 9" long and 1 3/8" wide. The velocity stacks are 1 1/4" long at a 45-degree angle from the runner. The fog used for visualization is produced by a fog machine using standard glycerin stage fog. The flow apparatus was placed against a black mat as a background. The fog machine was controlled by a pedal and introduced fog from the top of the apparatus. Both John Smith and I utilized handheld vacuums to drive the flow from the top of the plenum into the runners. The vacuums were alternated back and forth at a rate of one alternation every half second. The alternations were performed such that as one team member applied vacuum, the other plugged their respective runner. Dron Das Purkayastha recorded the entire scene on his camera.

Comparing the flow to the previous experiment, the most obvious difference was in the visibility of the Kelvin-Helmholtz instability. Just as before, 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), however now the instability was less pronounced with the longer runners in the new accurate 2D model. I believe this to be primarily due to the plugging of the runner during the alternations to simulate an intake valve closing in the real-world application. The end result was that the air in the plenum body was much less turbulent, which may characterize a more efficient geometry. Another keynote is that on the outside of the velocity stacks in *Figure 4*, it can be seen that air is not getting trapped under the bellend of the stack, also indicating an efficient geometry. A similarity between the first model and the model used in this project was the high vorticity in the trapped flow between the two velocity stacks. It may be worth seeing if optimizing the gap between the stacks would result in a more efficient flow.

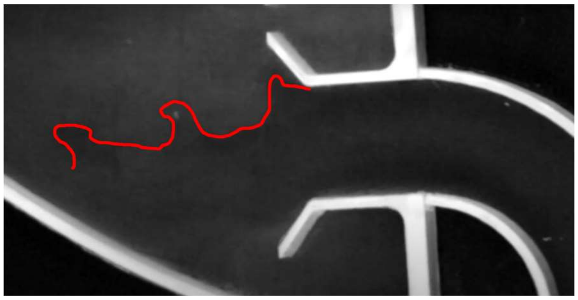


Figure 3: Slowed Kelvin-Helmholtz instability

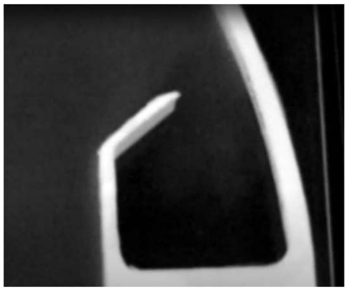
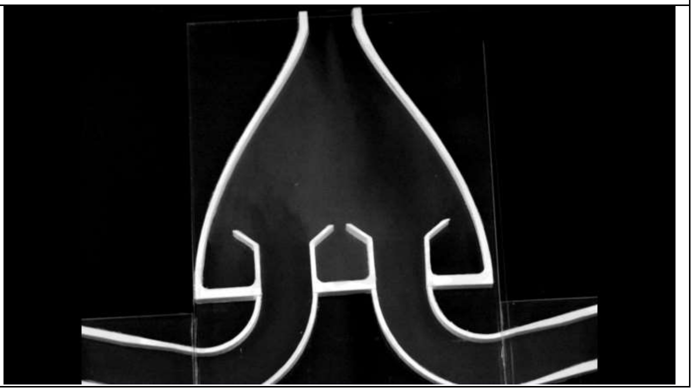


Figure 4: Flow remaining above the velocity stack

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 two backlights positioned above the apparatus by about two feet, with each light being about 90 degrees to either side of the camera. The backlights were positioned such that they would negate glare on the acrylic, a polarizing filter was used to idealize the scene. The video was recorded in a light-controlled room to give the best lighting; refer to *Figure 2*.

In the last experiment, we found that information was not lost in the quality of the video but rather in the framerate. The raw video was instead shot at 1280 x 720 at 120 frames per second with a Canon M50 Mark 1. Dron utilized his Canon ef 50mm, 1.8 prime lens with the ISO set to 200 and the shutter set to 1/500. The shutter was established to be best compatible with the slow-motion video, and the ISO was set for best exposure. The field of view was approximately 12”x16”. The camera was set such that the height of the frame encompassed the entire flow apparatus from the top of the plenum to the bottom of the runners, and the width was cropped in post processing to match the width of the flow apparatus at its widest point. Similar to the previous experiment, I maximized my exposure and contrast while dropping the saturation the get the greatest visual effect from the fog. In my editing I focused on the areas with the most information provided by the fog. I focused primarily on the flow effects around the velocity stacks during the transition between pulling vacuum on the runners. I also focused on the trapped vortices formed between the two velocity stacks. I sourced a royalty free audio clip, *Renewal* by Onycs for its slow piano and orchestral elements and set the clips to transition at lows in the track, giving the video a delicate feeling to match the gently stage fog.

Before	After
	

I am remarkably disappointed in the visualization this time around. I had selected stage fog to be a better analogue to the density of air compared to dry ice fog, however the glycerin lacked the texture and depth that dry ice fog championed. The raw video was again uninteresting; whereas before the editing revealed greater clarity, the glycerin lacked the depth to stand out even in the post processing. It seems as though the visuals achieved in editing this time around are equivalent to the visibility in the unedited flow in the prior experiment. While I am overjoyed with the physical model and the accuracy of the geometry, I fully intend to repeat this experiment for a third time using a visualization technique similar to that of the first run.

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