Design and Testing of a Smoke Rake System for the New ERAU Wind Tunnel

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Abstract

Smoke visualization is an extremely insightful technique to qualitatively understand complex flow fields, particularly in a wind tunnel environment. For this project, a smoke rake system was made to create trails of smoke called streaklines that follow the flow. This system helped to visualize flow around a test model used in student labs.

Figure 1. MicaPlex low-speed wind tunnel facility.

This work incorporates aspects of engineering design, construction, as well as testing and its various iterations providing exposure to an entire product life cycle.

Methods

Smoke generated in a pressurized plenum was fed through a pipe and PVC strut connected to the smoke rake. Prototypes of this design were fabricated using a 3D printer and tested in multiple configurations. The two parts that were printed were designed to fit onto the end of an existing metal aerodynamic strut that was later replaced.

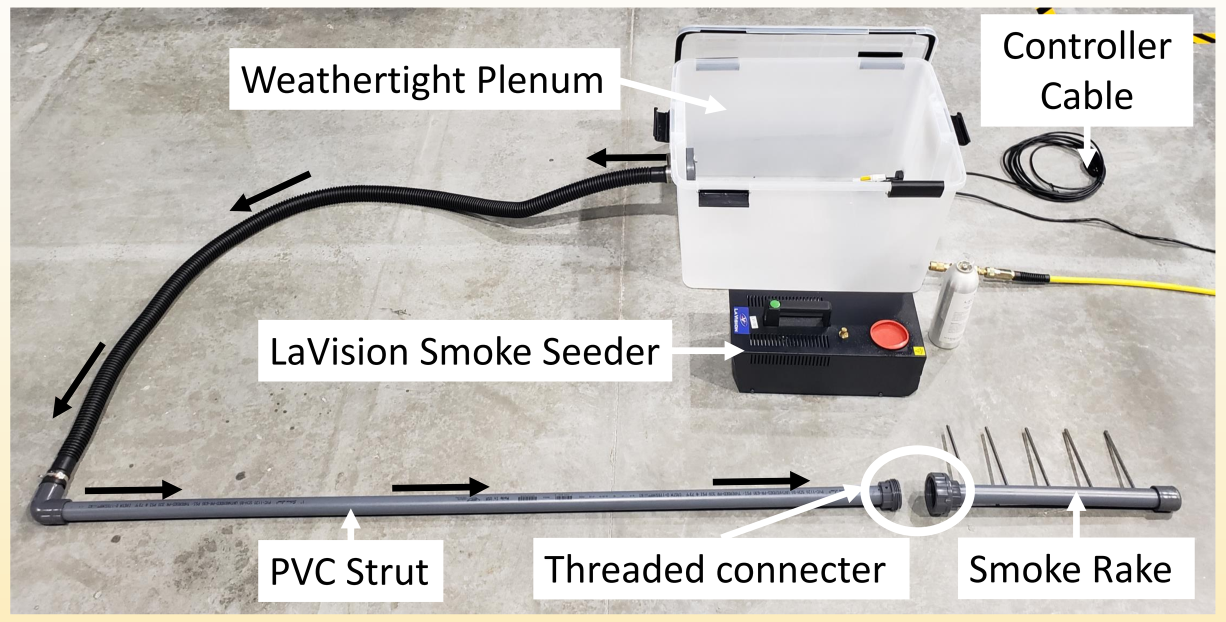


Figure 2. Smoke system with the smoke path represented by the black arrows.

Three existing pieces of equipment were utilized:

1. LaVision smoke seeder - Smoke generator with external controller
2. Traverse system - Electronically adjust the position of the smoke rake in the test section
3. Close-coupled canard delta wing model

Development

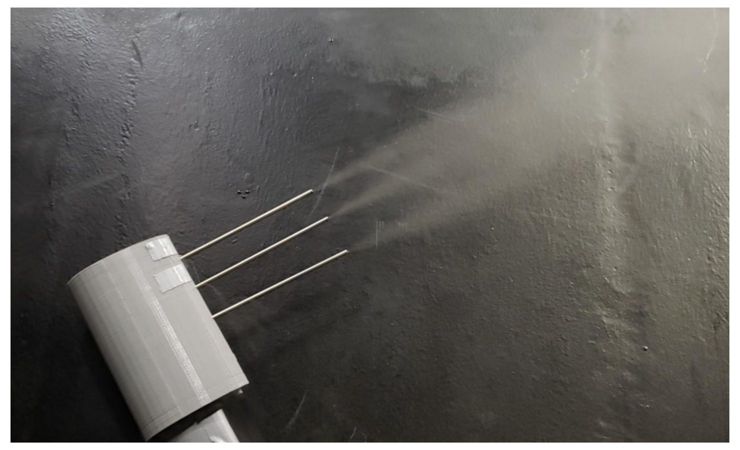


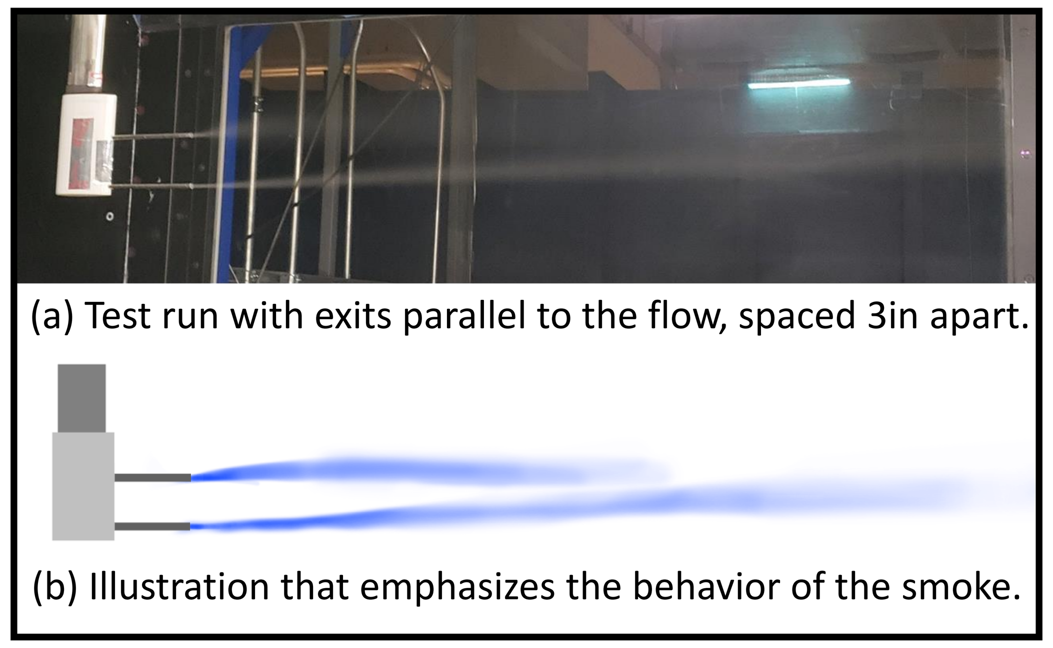
Figure 3. First test with 1/8 inch tubes.

Exit Diameter

The exit diameter effects the exit velocity, clarity of the smoke and pressure required in the plenum. The first test run used three 1/8 inch tubes. The test showed:

- The small exits made the streaklines thin and difficult to see.
- The plenum needed a higher pressure to push smoke out.

The exit tubes were changed to 1/4 inch tubes to allow the smoke to flow easier and produce more clear streaklines.



(a) Test run with exits parallel to the flow, spaced 3in apart.

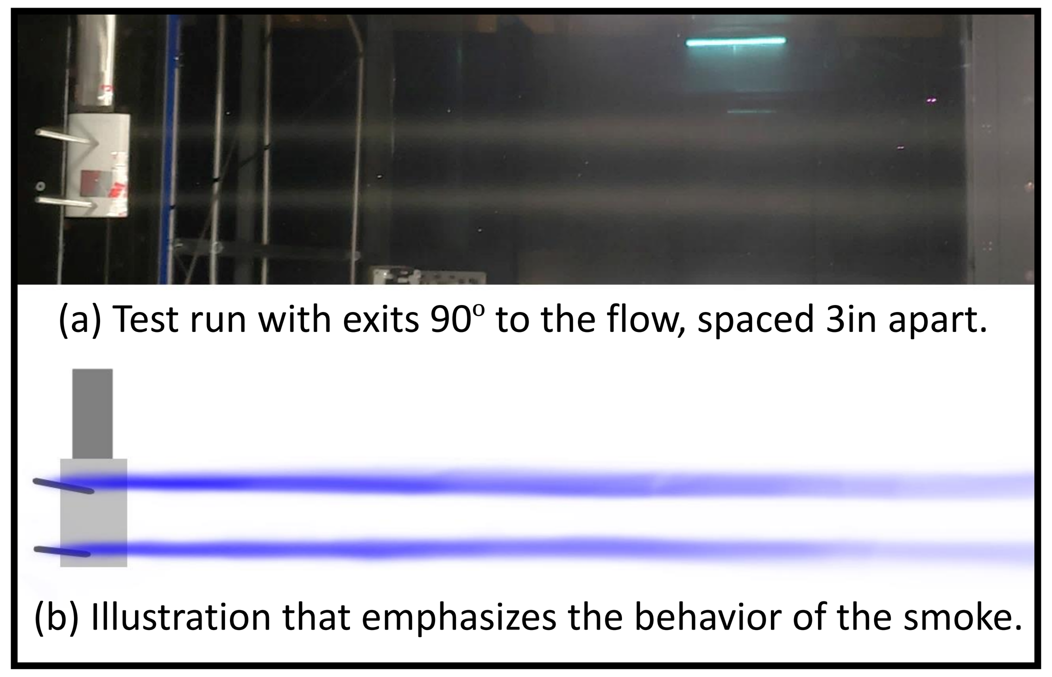
(b) Illustration that emphasizes the behavior of the smoke.

Figure 4. Smoke exits parallel to the flow caused the smoke to mix and have inconsistent behavior.

Exit Spacing

It was found that the spacing between the exit tubes effects how the streaklines interact with each other and the model.

- 1 inch spacing caused the smoke to mix and was not visible when flowing over the model.
- 2 inch spacing separated the streaklines, but it was still difficult to discern the flows behavior.
- 3 inch spacing provided clear, individual streaklines that didn't mix.



(a) Test run with exits 90º to the flow, spaced 3in apart.

(b) Illustration that emphasizes the behavior of the smoke.

Figure 5. Repositioning the exit tubes 90º created more consistent streaklines.

Exit Direction

Originally, an aerodynamic 3D printed part attached to a hollow streamlined strut was going to be used as the smoke rake like in figure 4. The smoke exits were parallel to the flow to theoretically allow the smoke to combine with the flow smoothly. However, during testing:

- Smoke diffused quickly and was difficult to see.
- Streaklines were constantly fluctuating.

Mixing occurred because the pressure inside the smoke rake was greater than that in the test section causing smoke to exit faster than the flow speed in the test section.

Figure 6. Final smoke rake design being tested.

To improve the quality of the streaklines, the exits were rotated 90º to be perpendicular to the oncoming flow. With this configuration:

- The smoke exit velocity is changed to match the velocity of the flow.
- The strut had less interference with the flow.
- The streaklines became more visible, consistent and easy to adjust.
- The shape of the strut and rake can be simplified since they have less interference with the streaklines.

Final Product

For the final design, smoke travels through a 1 inch PVC pipe and exits through five 6-inch-long, 1/4 inch diameter stainless steel tubes. A threaded connector on top of the rake is used to install it to a longer pipe attached to the traversal system. With this configuration:

- The smoke combined with the flow to produce long and consistent streaklines.
- The width of the streaklines could be changed by adjusting the input air and wind tunnel speed.

At 10ft/s, the smoke diffused quickly and created a sheet of smoke that was sensitive to minor fluctuations in the flow.

Figure 7. Sheet of smoke created at 10ft/s.

At 30ft/s, aerodynamic behavior such as turbulent flow and wingtip vortices could be characterized. This was the first time the flow was properly visualized with this model and gave insightful information about the interactions between the forward canard and the delta wing. This system can now be used during labs to provide a more in-depth learning opportunity for students.

Figure 8. Flow from the front canard wing can be seen effecting the streaklines in the center of the image.

Acknowledgments

- Dr. J. Gordon Leishman, Distinguished Professor of Aerospace Engineering & Director of the Wind Tunnel Annex, ERAU
- Dr. Zhang Zheng, Senior Research Scientist, ERAU
- Dr. Ebenezer Gnanamanickam, Associate Professor of Aerospace Engineering, ERAU