Manufacturing Nozzle for Smoke-Generator-Type Visualization System at MicaPlex Low-Speed Wind Tunnel

A. Aggarwal & J. D. Birjandi
Advisor: Dr. Z. Zhang & G. Greiner
Dept. of Aerospace Engineering, Embry-Riddle Aeronautical University, Daytona Beach, Florida, 32114

Abstract

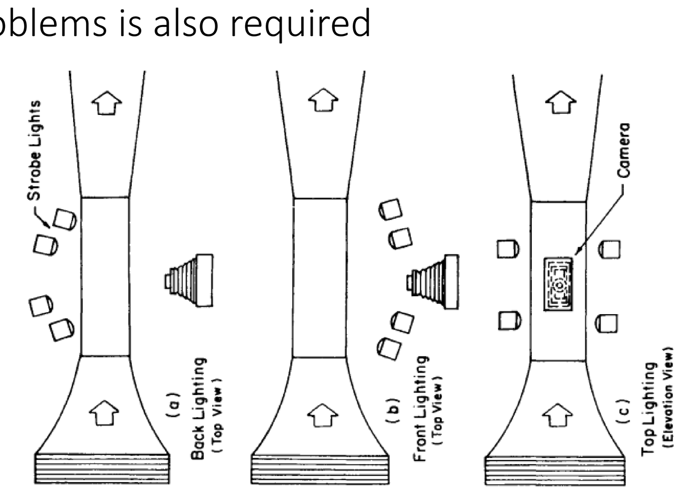
- Smoke visualization is a widely used method for studying the flow of fluids - particularly air - without the introduction of probes that may influence the character of the flow.
- The engineering focuses on the refurbishment of the existing smoke-generator-type visualization system at the MicaPlex Wind Tunnel facility to reduce mineral-oil deposits caused by the generator inside the pressurized plenum.
- Goal is to design, manufacture and test a venturi nozzle to substitute for the plenum.
- The nozzle is in its developmental phase and will act as a surrogate for the plenum.

Smoke Flow Visualization for Wind Tunnels

- Aerosol particles must be small enough to follow closely the flow pattered, but large enough to scatter for photographs
- Particles have Stokes number less than one; therefore, they can follow the flow
- Vaporization over combustion is preferred

Shows 2-D flow visualization over an airfoil at the Lehman Wind Tunnel Laboratory

- In wind tunnel application photography is extremely difficult due to space and lighting constraint
- Engineering requires proper illumination of smoke while maintain high contrast between background and smoke
- Management of low reflections and adverse heating problems is also required



Shows three commonly used lighting arrangement. a) Minimizes model glare b) back-scattered light particles is photographed, c) flow illuminated in the plane perpendicular to normal viewing (Yang, W.J. (2001). Handbook Of Flow Visualization (2nd ed.). Routledge.)

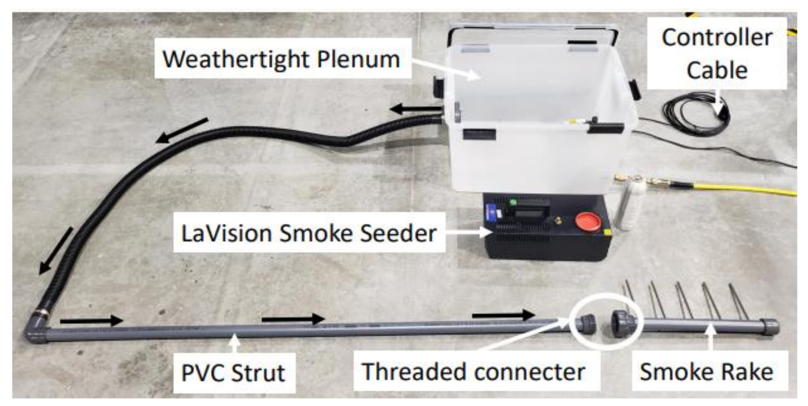
Full Abstract & Initial Calculation Link

Aggarwal, A., "Flow Visualization Venturi Nozzle Initial Design," *Beyond: Undergraduate Research Journal* (Not Yet Published).

Existing Smoke Rack Design Link

Ramirez, J., "Design and Testing of Smoke Rake System for the New ERAU Wind Tunnel," *Student Research Symposium,* November 2020.

Existing Smoke-Generator-Type Setup at MicaPlex Wind Tunnel

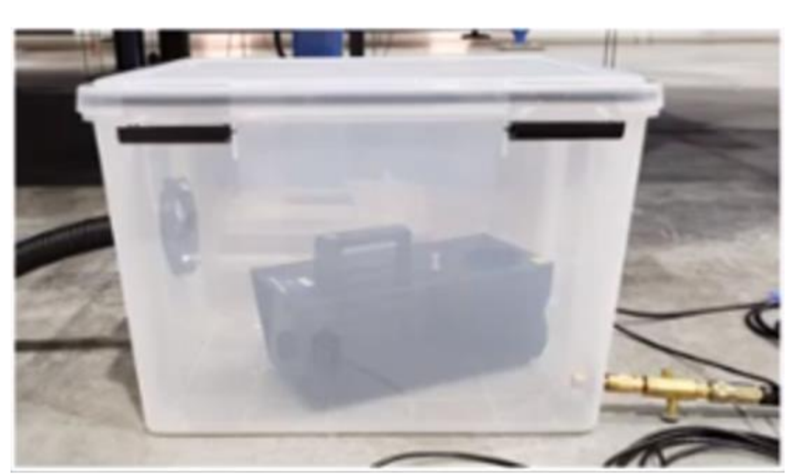


Ramirez's smoke flow visualizations setup which pressurizes the smoke by placing the smoke seeder inside the weathertight plenum.

Shows the results of Ramirez's smoke flow visualizations setup

Challenges & Issues with Current Design

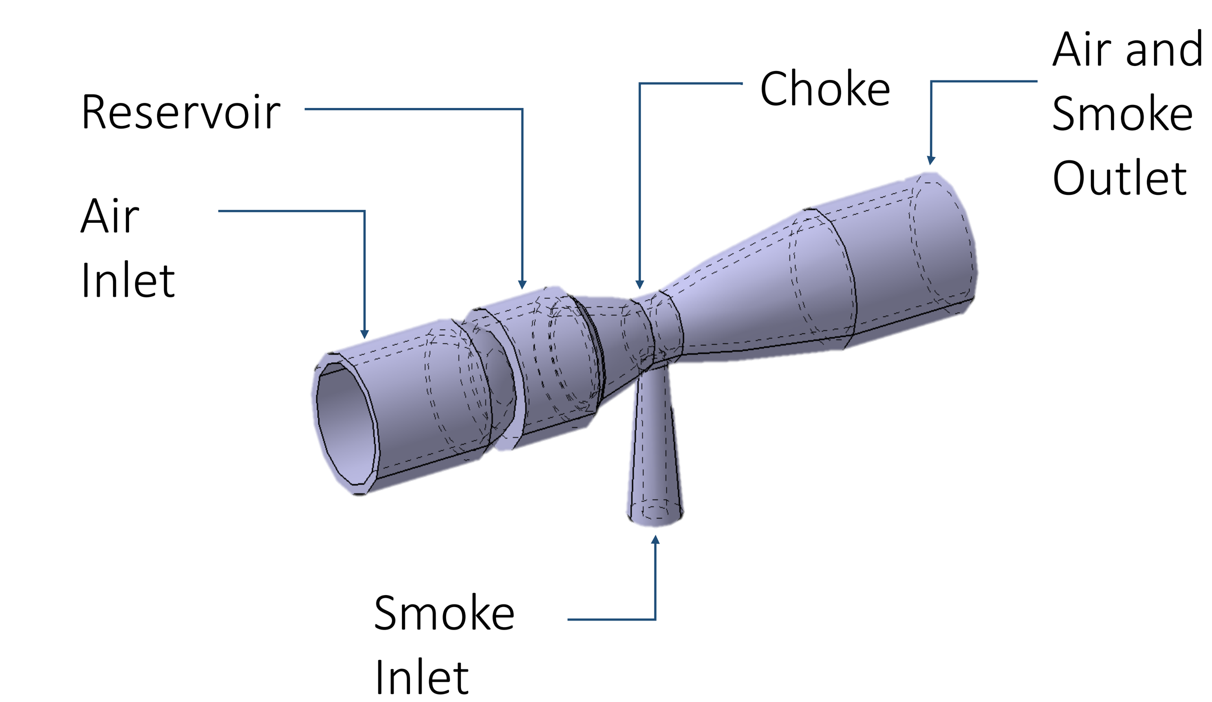
- The smoke diffusion rate is significantly high. The smoke streamlines are not visible throughout the testing body
- The pressurizing system – placing seeder in the plenum – leaves mineral oil deposits on the machine
- The smoke behavior is turbulent at low velocities



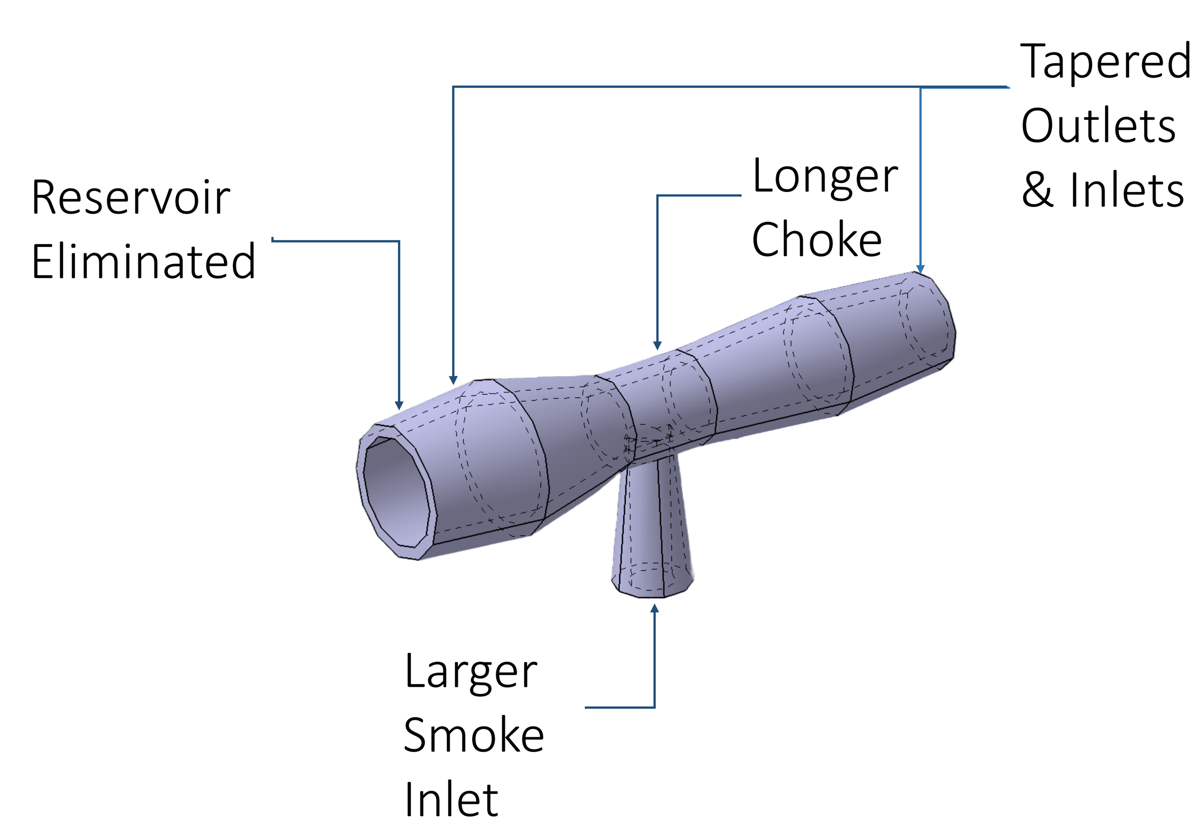
Shows smoke generator inside a pressurized container

Shows the sheet of smoke at 10 fps. The turbulence is smoke is visible and the streaklines. The flow is a dispersed two-phase flow.

First Iteration



Second Iteration



Estimated Flow Conditions

	Iteration 1	Iteration 2
Inlet Velocity	226 fps	226 fps
Inlet Pressure	25 psi	25 psi
Smoke Velocity	96 fps	63 fps
Outlet Pressure	23 psi	24 psi

Design Dimension

	Iteration 1	Iteration 2
Length	2.7 in	2 in
Inlet Diameter	½ in	½ in
Smoke Inlet Diameter	0.11 in	0.20 in
Choke Diameter	0.11 in	0.12 in
Outlet Pressure	¼ in	3/8 in

Design Assumptions & Engineering Methodology

- Steady
- Inviscid
- Incompressible
- Ideal Fluids
- No External Force (Body and Gravity)
- Two-Dimensional Flow
- Isentropic Flow

- The first nozzle was designed by incorporating the diffusion coefficient equation as well the density of smoke.
- The second iteration was designed by assuming a single density to enable single phase assumption and reduce errors in the derived continuity, energy and momentum equations.
- After initial calculations, the nozzles were sent for manufacturing. However, PLA and ABS 3D printers were unable to manage the brevity of the nozzle. The nozzles were printed using engineering resin.
- Test were completed and the results were analyzed for better design suggestions.

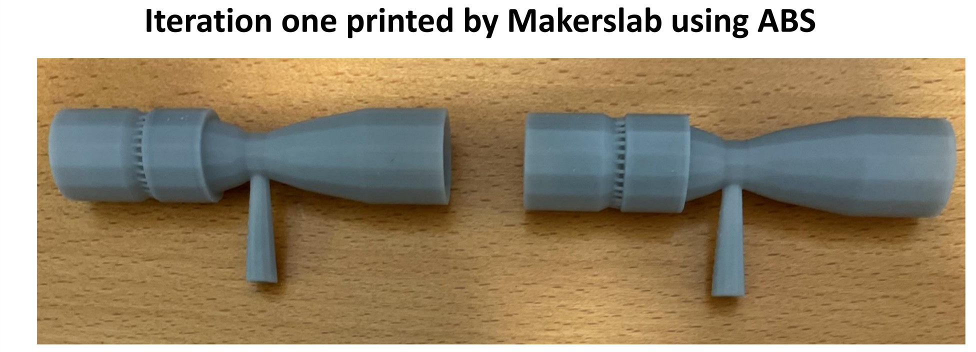
Iteration One

Iteration Two

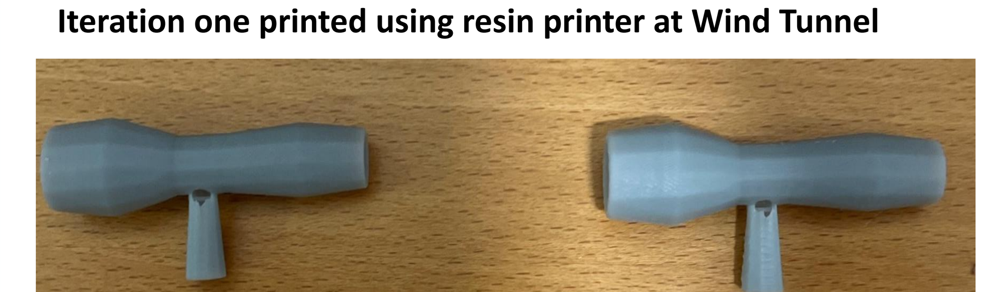
Results and Continued Work

Test setup - duct & plumber's tape was used to secure the nozzle

Iteration one printed by Makerslab using ABS



Iteration one printed using resin printer at Wind Tunnel



Iteration two printed using resin printer at Wind Tunnel

1. The first iteration was printed using Acrylonitrile Butadiene Styrene. However, the smoke inlet was not able to support itself and broke off
2. Subsequently, resin printer was used to manufacture the nozzles
3. The second iteration could not be printed properly. Structural holes developed on the smoke inlet
4. Dry test runs with shop compressed air showed weak suction at the choke; however, the mass flow rate might be too low

Continuous work is in progress. Recalculation and new geometry is being defined to increase suction, wall thickness and simplify exterior shape. Manufacturing feasibility will also be a major component of interest in the following iterations