Measurement of Black Carbon Concentration in Emissions from a Capstone C30 Microturbine

Rebecca Gardner
Faculty Mentor: Dr. David Kittelson
Thomas E. Murphy Engine Research Laboratory, Mechanical Engineering, College of Science and Engineering

MOTIVATION

- Aircraft exhaust contains particulate matter (PM) that arises from incomplete combustion of fuel and lubrication oil in the gas turbine. Non-volatile carbonaceous PM is commonly referred to as soot, and the portion of soot that is light-absorbing is known as black carbon (BC)[1].
- The United States Federal Aviation Administration has projected that U.S. passenger aviation transport will increase as much as 42% over the next 20 years[2]. This increase in aviation traffic has brought further attention to the negative effects of BC emissions:
  - BC has been deemed to be the second-most important global climate-forcer after carbon dioxide[3].
  - BC also contributes to the formation of photochemical smog and increases the potential for people to inhale highly concentrated irritants[4].
- This study seeks to further our understanding of BC emissions by running a Capstone C30 microturbine (essentially a scaled down aircraft gas turbine) on fuels with a variety of compositions.

METHOD

- Emissions from the Capstone C30 were characterized by measuring both mass and number concentration of BC in the microturbine's exhaust for different fuels
- The main instruments used for these measurements were the scanning mobility particle sizer (SMPS) and the condensation particle counter (CPC)
- Both diesel fuel and Jet A were mixed with varying concentrations of 3 dopants: xylene, benzene, and naphthalene
- The dopants were expected to cause the BC concentration to vary

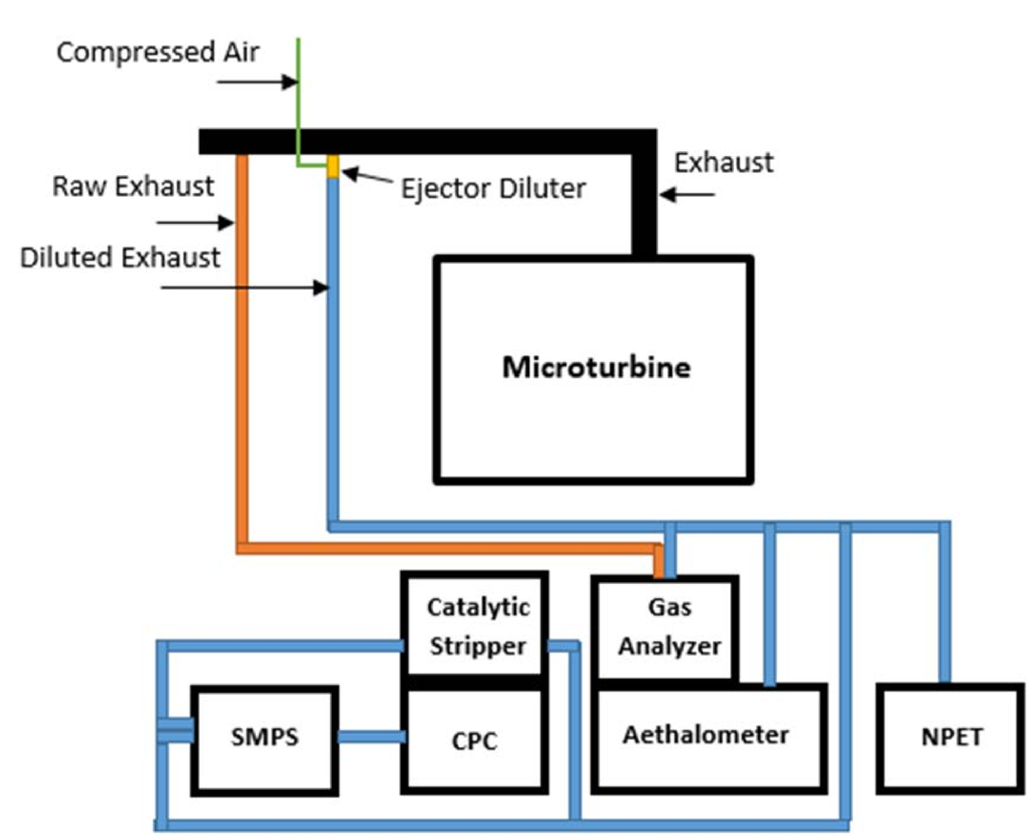

Figure 1: Experiment schematic. Note that additional instruments in the schematic not mentioned above were used to collect additional data not crucial to the main objective of this experiment.

COMPLETED WORK

- Initial measurements of BC particles while running the turbine with diesel were extremely low, so diesel was doped with xylenes, and then benzene to obtain higher measurements
- Benzene generated a slightly larger number of particles than xylenes, so a higher concentration was used in a third test
- All three tests produced very little particles overall, as can be seen from the data in Figure 2 below

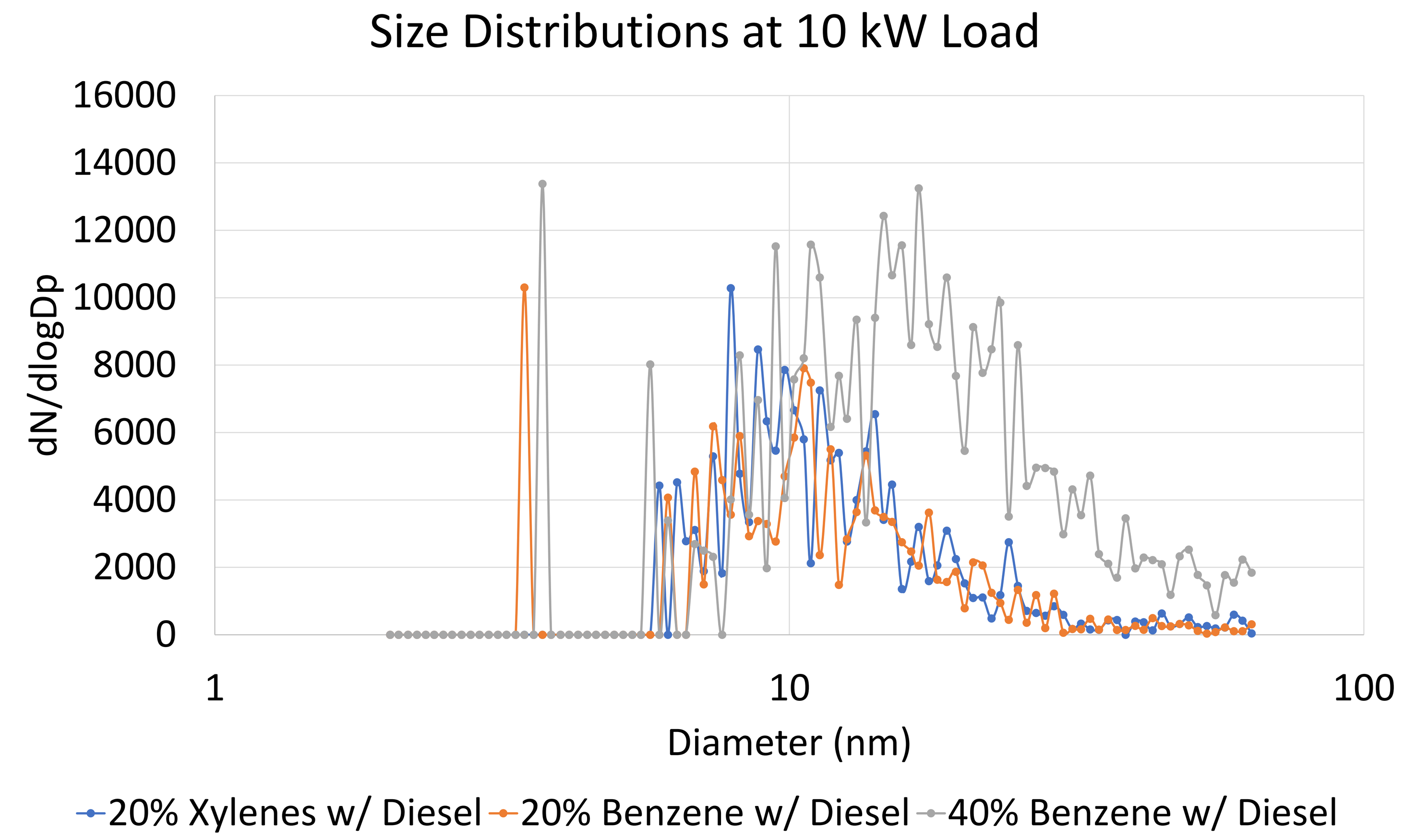

Figure 2: The three tests that this graph compares were each run using a different fuel composition at a 10 kW load.

- After diesel, Jet A was tested to determine if it would produce a greater number of particles
- When it did not produce much BC on its own, it was also doped with benzene
- The results of these tests are below in Figure 3. Once again, among all tests conducted, very little particles were produced

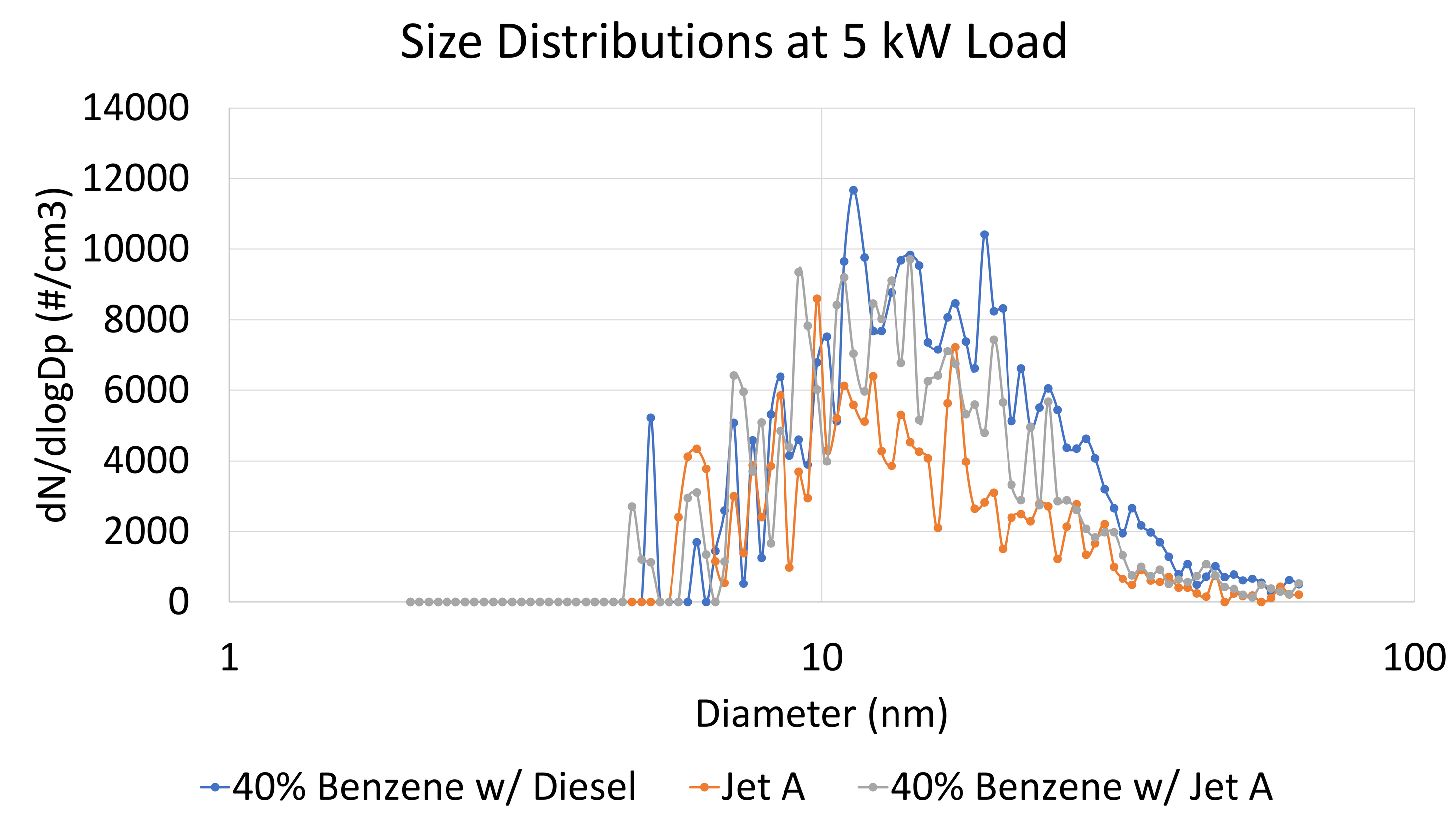

Figure 3: The three tests that this graph compares were each run using a different fuel composition at a 5 kW load.

FUTURE WORK

- Further research to determine whether or not emissions of other microturbine models are similar to that of the Capstone C30
- Determine why the Capstone C30 itself is so clean, and why it is not more widely used
- Study of differences between aircraft APUs and microturbines to ascertain why APUs have more emissions.
- Tests run with different fuel compositions with different dopants than the ones used in this study may be attempted

SIGNIFICANCE

- Research will contribute to existing microturbine emissions literature
- The experimental set-up for this study can be used for future emissions and fuel sensitivity research with the Capstone C30
- Discovering the clean nature of the Capstone C30 may allow for further breakthroughs in efforts to mitigate BC emissions, both in aircraft and microturbines.

REFERENCES

1. Boies, A., Stettler, M., Swanson, J., Johnson, T., Olfert, J., Johnson, M., Eggersdorfer, M., Rindlisbacher, T., Wang, J., Thomson, K., Smallwood, G., Sevcenco, Y., Walters, D., Williams, P., Corbin, J., Mensah, A., Symonds, J., Dastanpour, R., and Rogak, S., 2015, "Particle Emission Characteristics of a Gas Turbine with a Double Annular Combustor", Aerosol Science and Technology, 49(9), pp. 842-855.
2. Federal Aviation Administration, 2016, FAA Aerospace Forecast.
3. Carleton University, 2017, Field Measurements of Black Carbon Emissions from Flaring in Ecuador: Analysis of Results from Field Measurements Performed near Coca, Ecuador, June 2-5, 2014, Carleton University, Ottawa.
4. Lobo, P., Hagen, D., Whitefield, P., and Alofs, D., 2007, "Physical Characterization of Aerosol Emissions from a Commercial Gas Turbine Engine", Journal of Propulsion and Power, 23(5), pp. 919-929.

ACKNOWLEDGEMENTS

I thank professors David Kittelson and Jacob Swanson for their guidance and assistance, and for the opportunity to conduct this study. This project was supported by the University of Minnesota's Undergraduate Research Opportunities Program.