Evolution of soot size distribution & nanostructure during enclosed spray combustion of jet fuel

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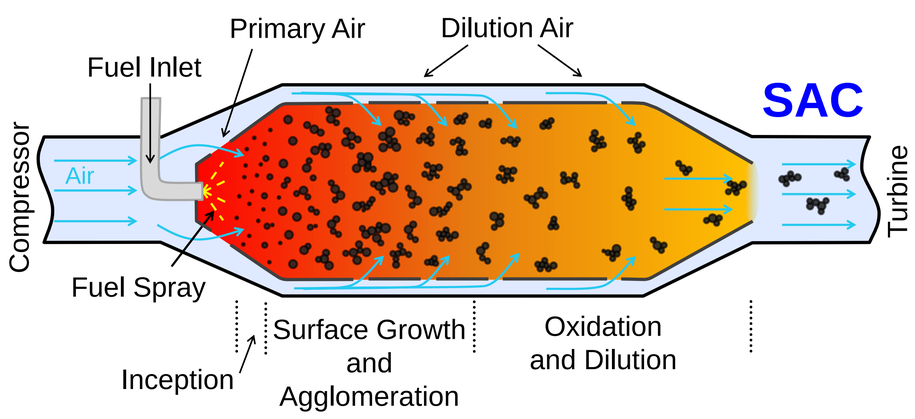
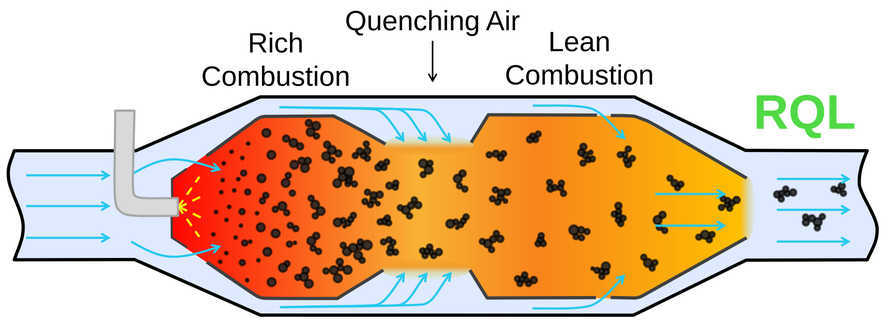
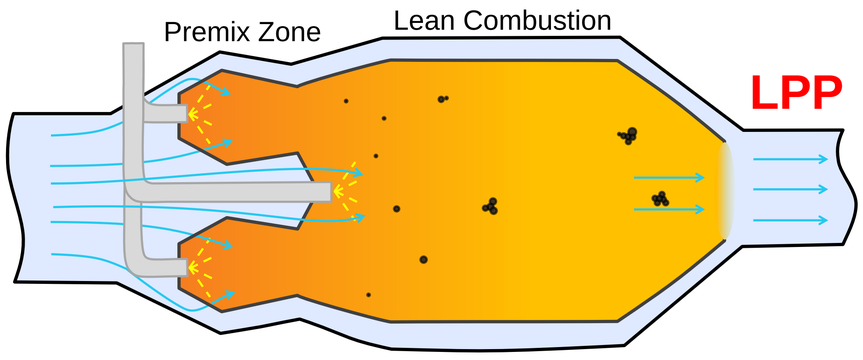
Motivation

Aircraft engines produce ultrafine soot that degrades health and the climate. Understanding jet fuel soot formation and growth is essential for designing combustors that lower soot emissions without increasing the production of other pollutants. Here, enclosed spray combustion of Jet A1 fuel that nicely emulates aircraft emissions[1] is used to understand formation of aircraft-like soot as tests on real aircraft are too costly or inaccessible.

Soot Formation in Aircraft Combustors

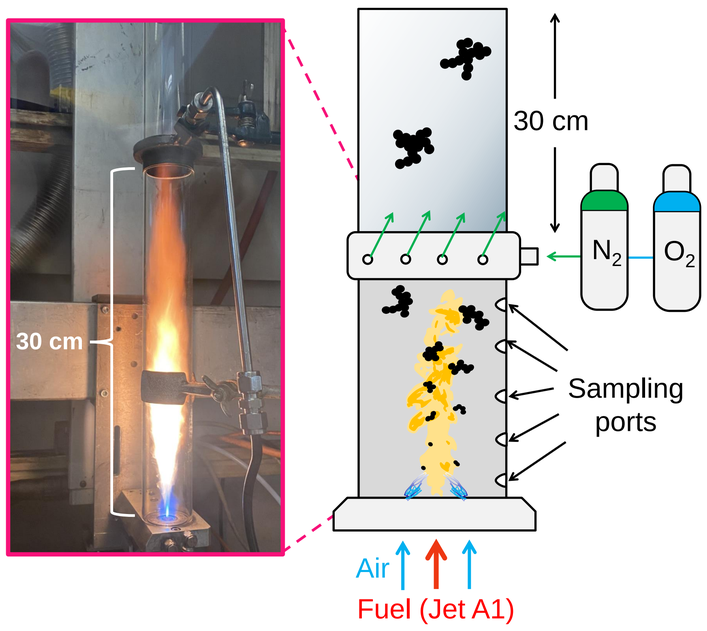






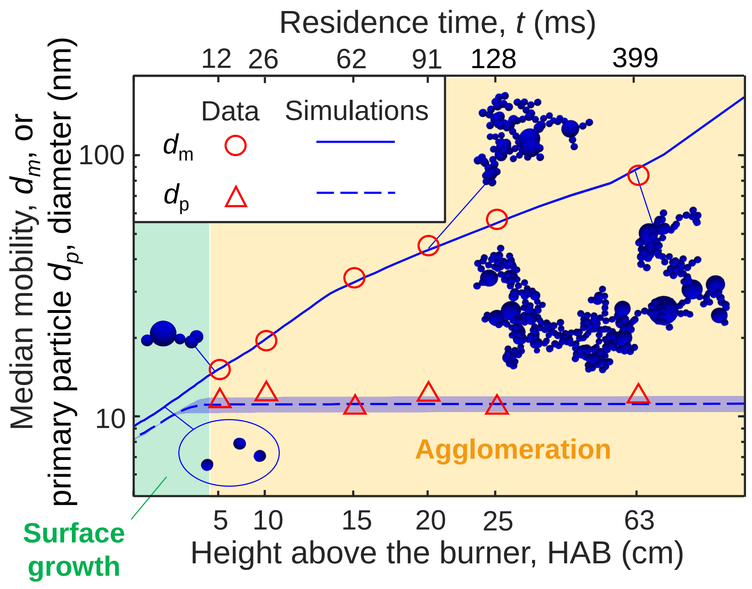
Soot dynamics in a Single Annular aircraft Combustor (SAC), a Rich-Quench-Lean (RQL) & a Lean Premixed Prevaporized (LPP) combustor.

Aircraft-like Soot Generator



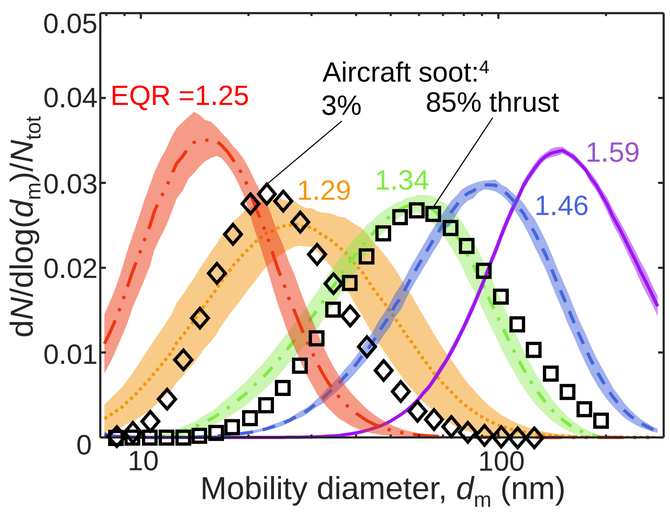
Generator with a torus ring injecting 20 L/min of N_2 or O_2 with aerosol sampling locations.

Surface Growth & Agglomeration



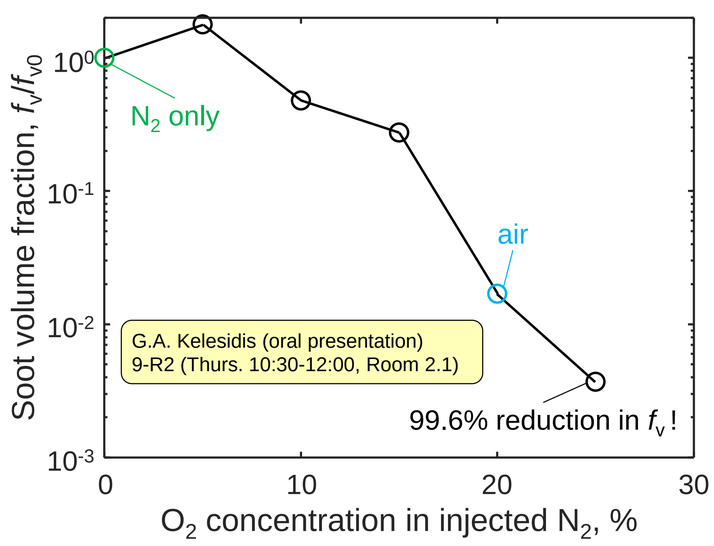
Soot measurements in excellent agreements with Discrete Element Modeling simulations.[2]

Soot Size Range



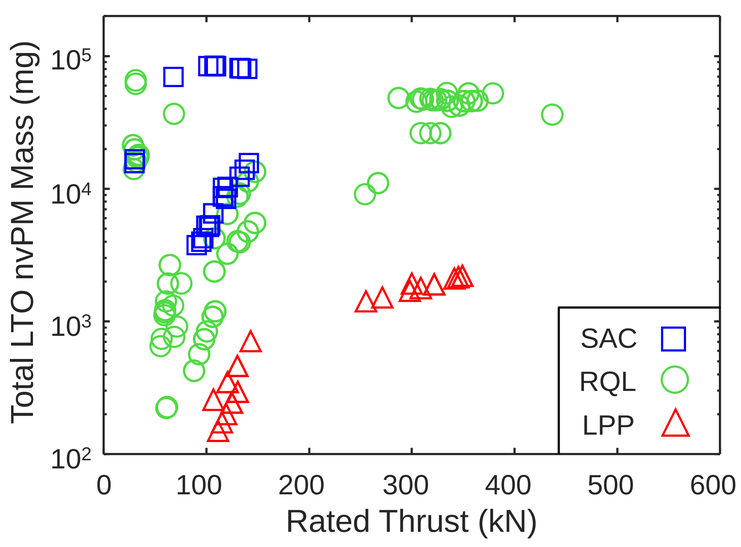
Normalized mobility size distributions at various equivalence ratios (EQR). Shades around the lines represent the standard deviation between measurements.

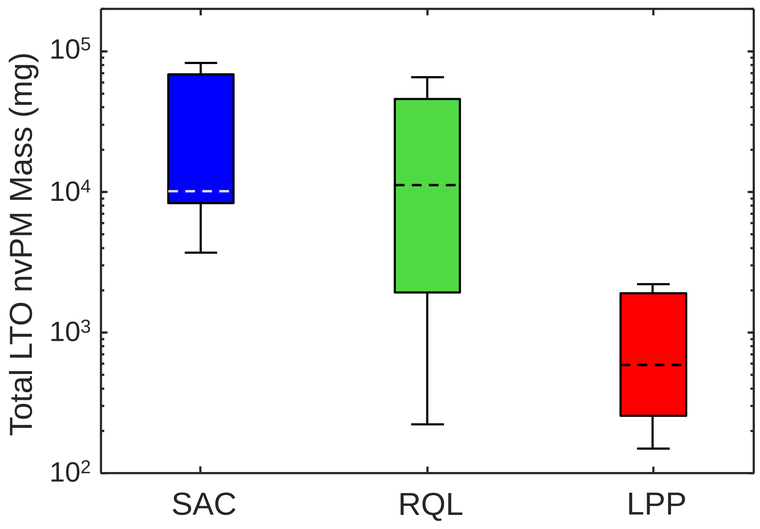
RQL-like Oxidation of Soot



The effect of O_2 addition to the torus ring supplying N_2 on the soot volume fraction, f_v.

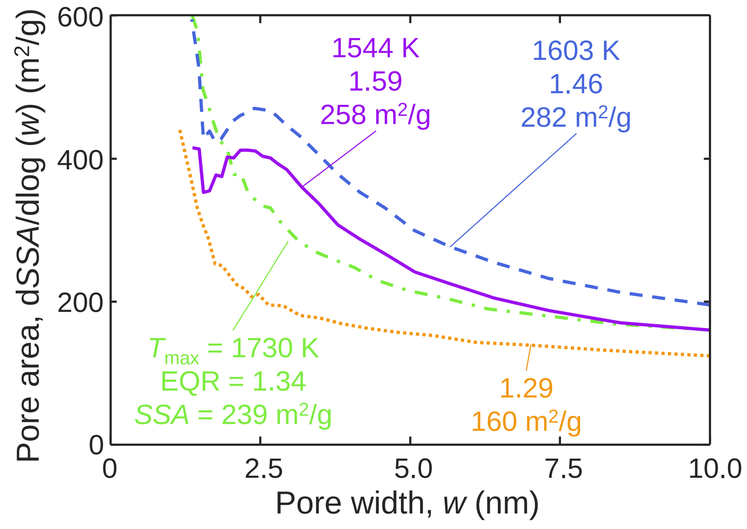
nvPM Emissions by Combustor Type





Total mass non-volatile Particulate Matter (nvPM) from the standard Landing and Take-off (LTO) cycle by an engine's rated thrust[3] from the dominant aircraft combustors.

Specific Surface Area (SSA)



Pore size distributions & SSA of soot made at EQR = 1.59, 1.46, 1.34 and 1.29

References

[1]Trivanovic, U., Kelesidis, G.A., Pratsinis, S.E. (2022), *Aerosol Sci. Technol.* 56, 732-743.

[2]Trivanovic, U., Pereira Martins, M., Benz, S., Kelesidis, G.A., Pratsinis, S.E. (2023) *Fuel* 342, 127864.

[3]ICAO (2023) *Aircraft Engine Emissions Databank* (Accessed 20/08/2023) www.easa.europa.eu/en/domains/environment/icao-aircraft-engine-emissions-databank

[4]Abegglen, M, Durdina, L., Brem, B.T., Wang, J., Rindlisbacher, T., Corbin, J.C., Lohmann, U., Sierau, B. (2015) *Aerosol Sci.Technol.* 88, 135-147.

Conclusions

1. Lean Premixed Prevaporized combustors have the lowest soot emissions by eliminating fuel rich zones.
2. Enclosed spray combustion of jet fuel can be used to simulate aircraft soot in the laboratory.
3. Large quantities of soot allow for critical measurements such as the specific surface area which is difficult to obtain from actual aircraft emissions.

Una Trivanovic (oral presentation)
9-R2 (Thurs. 10:30-12:00, Room 2.1)