Carbonaceous aerosol formation & growth by enclosed spray combustion of hydrocarbons

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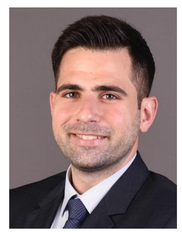
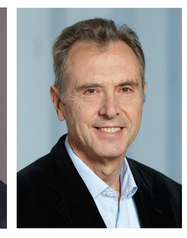

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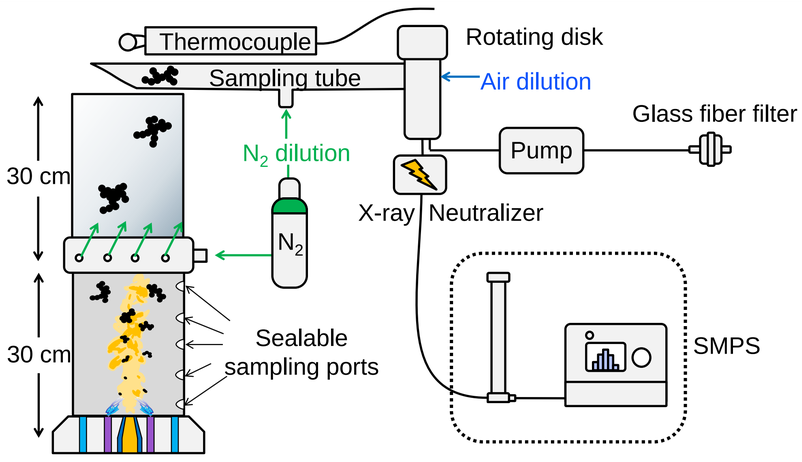
Motivation

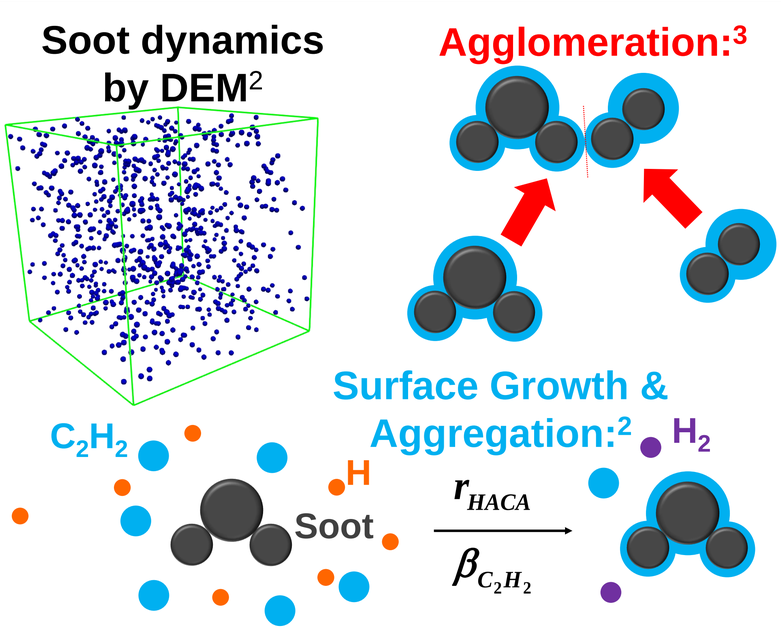
Understanding the dynamics of soot nanoparticles during combustion of jet fuel is essential for mitigating the impact of aircraft engine emissions on health and climate. Here, soot formation during enclosed spray combustion of jet fuel [1] is investigated by discrete element modelling (DEM) [2] and by microscopy, particle mobility & Raman spectroscopy measurements.

Experimental set-up

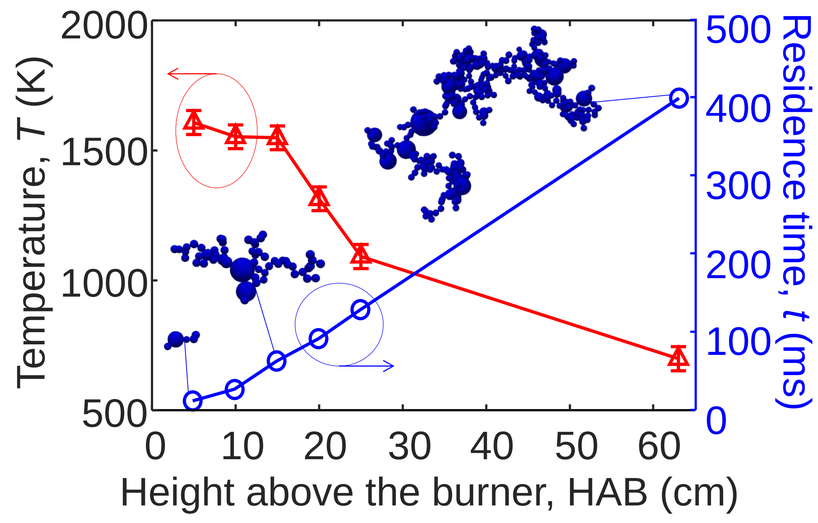


The experimental set-up[1] (not to scale) of enclosed spray combustion where a spray of jet A1 is ignited with a premixed methane flame and surrounded by sheath air. Sampled soot is diluted and distributed to a scanning mobility particle spectrometer (SMPS) or glass fiber filter for offline analysis.

Discrete Element Modelling

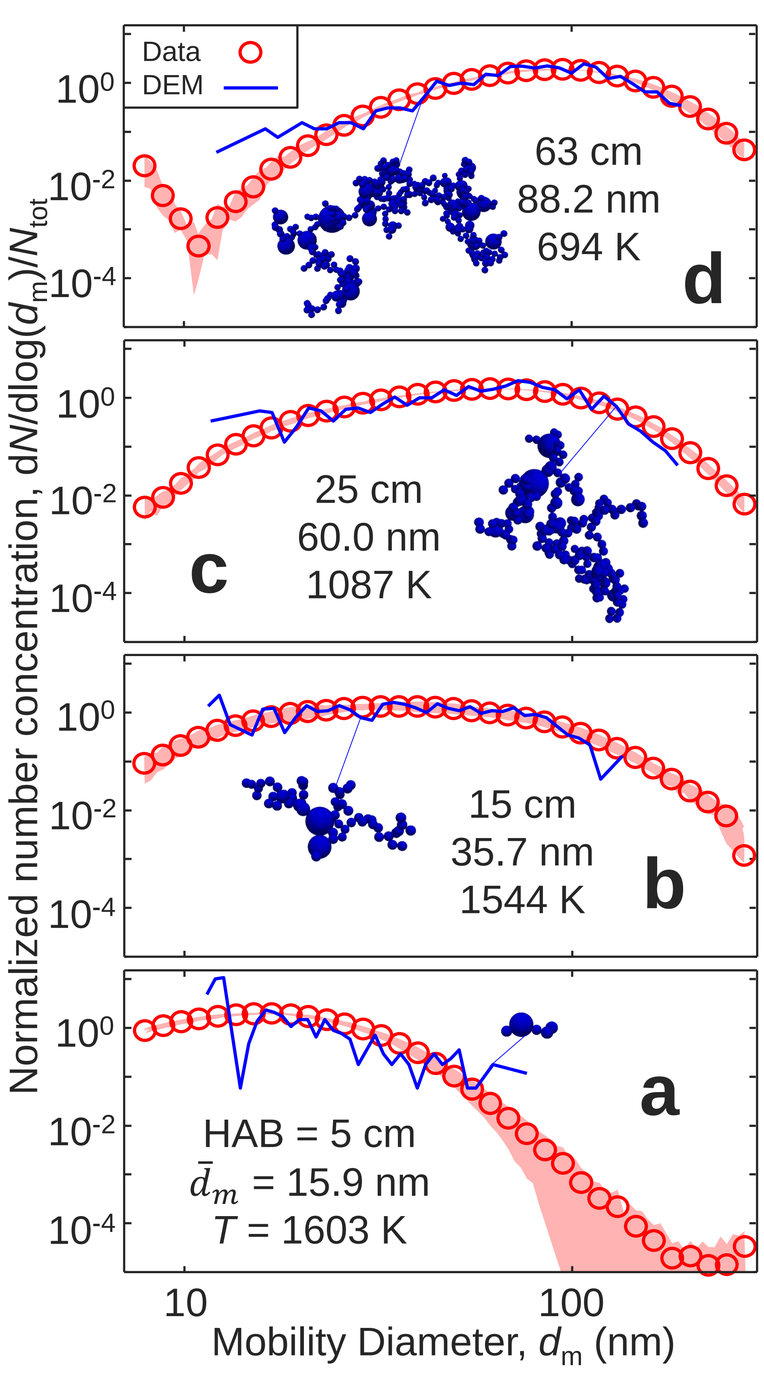


In-flame temperature



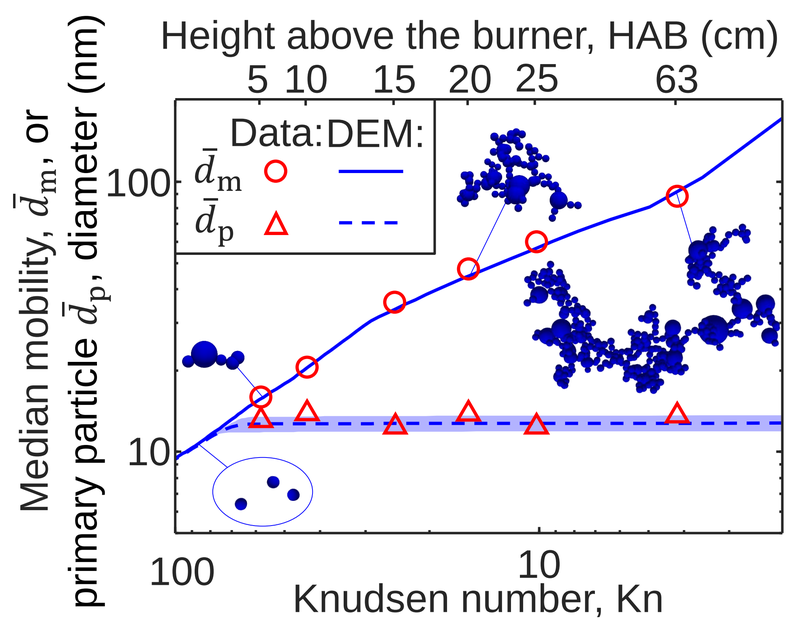
Flame temperature, T, (left axis) as a function of HAB during enclosed spray combustion of jet fuel at EQR = 1.46 (triangles) and the residence time, t (right axis).

Mobility size distributions



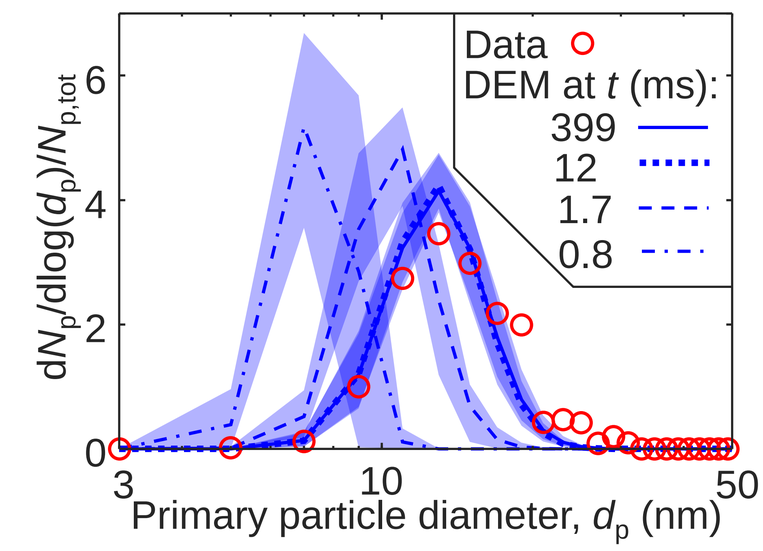
Mobility diameter, d_m, distributions of soot produced by enclosed spray combustion of jet fuel at EQR = 1.46 and (a) HAB = 5 cm, (b) 15 cm, (c) 25 cm and (d) 63 cm from experiments (symbols, shaded area) and DEM simulations (lines).

Evolution of morphology with HAB



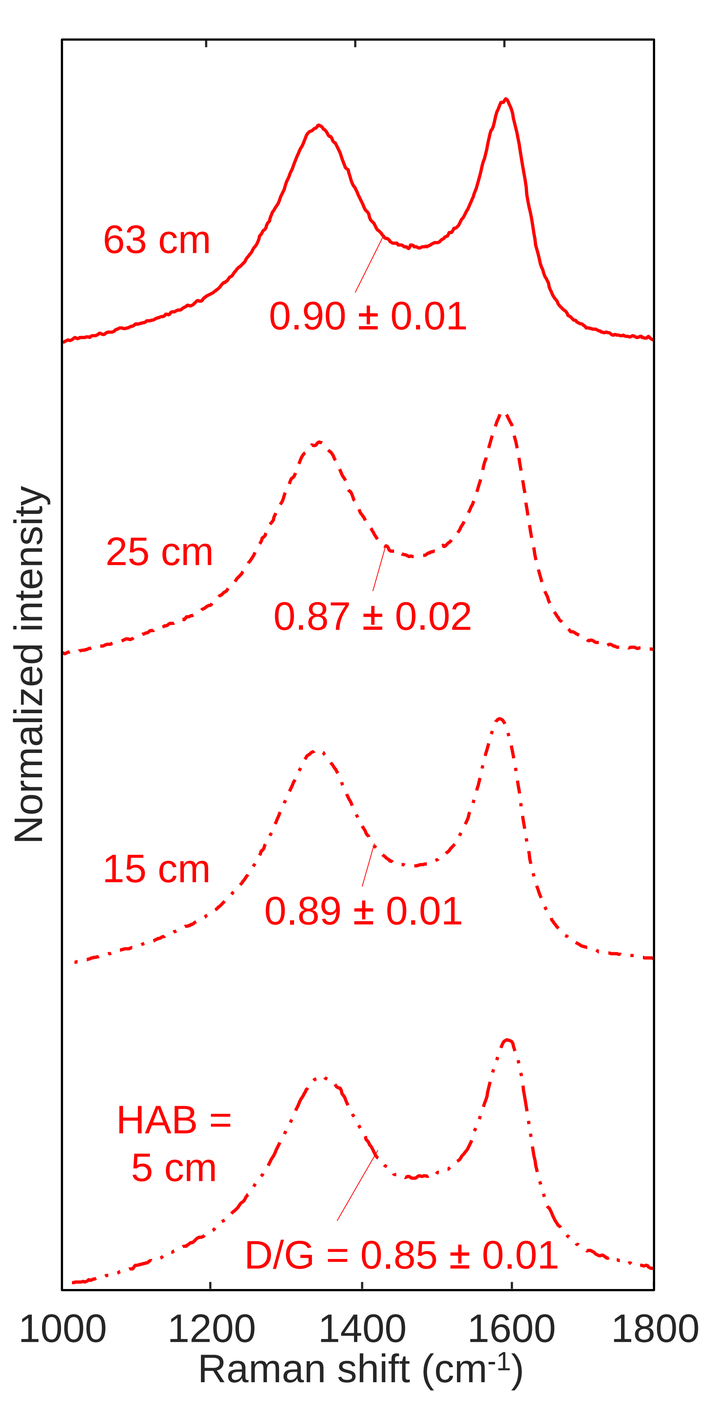
The median mobility, $\bar{d}_m$, (circles, solid line) and primary particle $\bar{d}_p$, (triangles, broken line) diameter as a function of the Knudsen number (bottom axis) or height above the burner, HAB, (top axis) from experiments (symbols) and DEM simulations (lines).

PP size distributions



The PP distributions of soot at EQR = 1.46 at HAB = 63 cm from experiments (symbols) and DEM at t = 399 (solid line), 12 (dotted line), 1.72 (broken line) and 0.82 ms (dot-broken line).

Raman spectra



Normalized intensity as a function of Raman shift from soot produced by jet fuel spray combustion at EQR = 1.46 at HAB = 5 cm (double dot-broken line), 15 (dot-broken line), 25 (broken line) and 63 cm (solid line).

References

[1] Trivanovic U, Kelesidis GA, Pratisnis SE. (2022) *Aerosol Sci Technol* **56** 732.
[2] Kelesidis GA, Goudeli E, Pratsinis SE. (2017) *Proc Combust Inst* **36**, 29.
[3] Kelesidis GA, Goudeli E, Pratsinis SE. (2017) *Carbon* **121**, 527.

Conclusions

1. Soot formation during enclosed spray combustion of jet fuel is investigated both numerically & experimentally, for the first time to the best of our knowledge.
2. At short *t* and low HABs (< 5 cm), soot $\bar{d}_p$ and D/G ratio increase up to 14 nm and 0.9, respectively, mostly by surface growth.
3. As *t* increases at large HABs, agglomeration takes over and increases soot $\bar{d}_m$ from 16 to 88 nm without altering its $\bar{d}_p$ and D/G ratio.
4. The DEM-derived mobility and primary particle size distributions are in excellent agreement with those measured at HAB = 5 – 63 cm.