Developments in nvPM Loss and Transport when Sampling Aircraft Gas Turbine Engine Combustion Emissions

Fergus Lidstone-Lane[a,c], Paul Williams[a], Amanda Lea-Langton[a], Mark Johnson[b], Adam Boies[c]
a.University of Manchester, b.Rolls Royce, c.University of Cambridge
Contact: fergus.lidstone-lane@postgrad.Manchester.ac.uk

Project Background

- Aircraft engine combustions emissions have a significant impact on the environment and public health, with a predicted 16,000 premature deaths annually[1].
- Regulatory requirements outline emissions measurements for aircraft engines[2]. Which have resulted in the development of sampling systems to measure aircraft engine emissions[3].
- Due to the complex nature of aircraft engine emissions, large losses of nvPM occur when sampling[4].
- Several regulatory methodologies have been established to account for nvPM losses, however there are various assumptions and limitations[5].
- This poster shows some developments from year.2.

Project Aims

- Quantify nvPM losses from various aerosol loss mechanisms to improve regulatory and sampling system methodologies.
- Develop new sampling probes to sample nvPM closure to the combustion chamber for better combustion understanding.
- Build nvPM CFD models to help design new emissions instrumentation and add to regulatory requirements

Methods used in Year.2

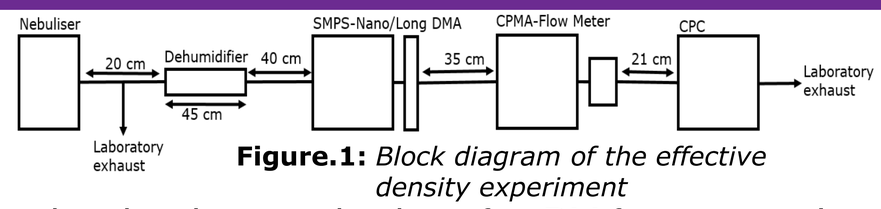
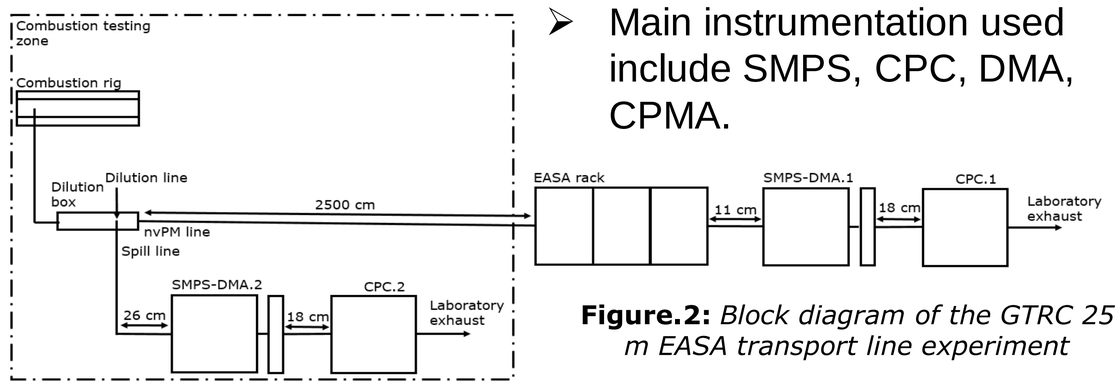


Figure.1: *Block diagram of the effective density experiment*

- Effective density characterisation of nvPM from a novel suspension method – Figure.1. Key activity for the investigation of a new particle generation method that is representative of aircraft nvPM.
- nvPM loss characterisation through the 25 m EASA sampling system transport line when the upstream SMPS was sampling from a new location (vent dilution box) – Figure.2. This experiment was used to assess the effects of sampling from a new location and if it agrees with nvPM loss models



- Main instrumentation used include SMPS, CPC, DMA, CPMA.

Figure.2: *Block diagram of the GTRC 25 m EASA transport line experiment*

Key Results from Year.2

- Figure.3 and Figure.4 show similar trends – novel method of suspension has fairly good agreement with past experimentation.
- Both black carbon (solid orange and blue lines) show very good agreement, along with aircraft soot (dashed purple line). Hydrogenated aircraft soot line shows possible inconsistencies.
- As expected, the general trend is a decrease in effective density with an increase in diameter.
- All lines start around 1,600 kg/m^3 – very good agreement with previous experimentation.
- Overall, novel suspension methods can be expected to be representative of aircraft soot sampled directly from the aircraft engine exhaust. Although this may not be true for hydrogenated aircraft engine soot.

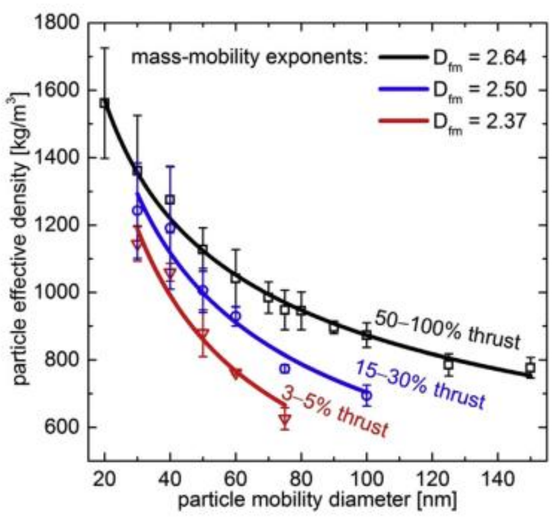


Figure.3: *Effective density of aircraft engine soot measured directly from the exhaust*[6].

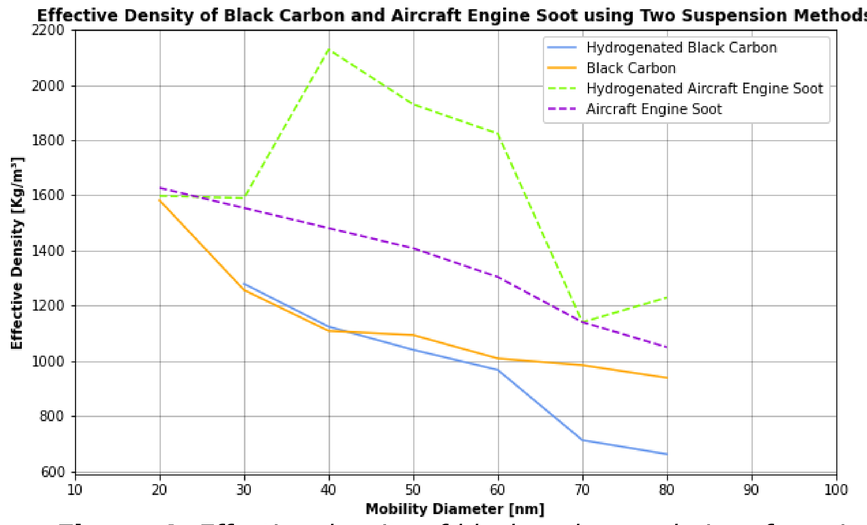


Figure.4: *Effective density of black carbon and aircraft engine soot measured from a novel solution.*

- Figure.5 shows good agreement between the experimental measured values and the UTRC model below 20 nm.
- Above 20 nm the experimental measured values deviate from the UTRC model and there is a small peak present indicating a possible mode.
- Other aerosol sizing instruments (DMS vs DMS and EEPS vs SMPS) used on this experimentation campaign showed similar results.
- This indicates that the UTRC model is over predicting at the large size ranges when sampling from the new location or that the new location for sampling is not an acceptable place to sample from.

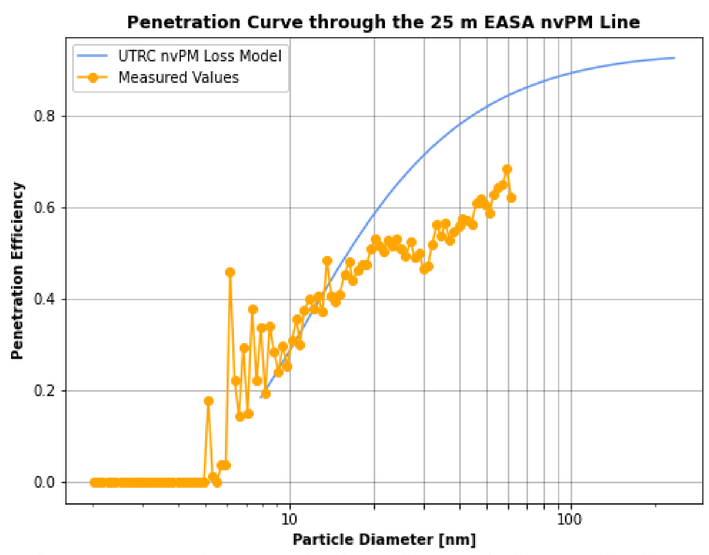


Figure.5: *nvPM penetration through the EASA 25 m nvPM transport line with the UTRC model shown for comparison.*

Year.2 Summary and Future Work

- Effective density of black carbon, hydrogenated black carbon, and aircraft engine soot using the novel suspension methods is similar to previous experiments when sampling directly from the exhaust, meaning that the suspension methods are an acceptable sources of soot.
- Sampling from the new location from the combustion rig gives similar penetrations efficiencies below 20 nm as predicted by the UTRC model, however above this there is not an agreement. This suggest that sampling from this location does not give accurate results.
- Continuation of COMSOL model development to design a Total Particle counting instrument – specifically modelling semi-volatile loss on walls.
- Investigation of nvPM loss on pipe inner walls from pipe surface roughness. Theoretical model development and experimental validation.
- nvPM sampling probe tip design and test. Will mostly be completed as part of an internship at Rolls Royce in 2023.

References

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