Effective density of aircraft engine PM revisited: Effects of engine thrust, engine type, fuel, and sample conditioning

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Aircraft gas turbine engines emit soot agglomerates with varying size, shape, and composition as a function of their operating condition. A useful parameter, which accounts for particle morphology, is effective density. Effective density is used to relate particle number and mass emissions in aviation PM emission models. However, measurement data of PM effective density from commercial aircraft turbine engines are very limited.

Here, we report the size-dependent effective density of PM sampled from commercial aircraft turbine engines in an engine test cell using a standardized sampling and measurement system. We used tandem DMA-CPMA classification as in our previous study (Durdina et al. 2014). The novelty of this work is reduced scan time from over 10 minutes down to 1 minute per sample with the same hardware configuration, wider range of particle sizes, measurement of different engines, and a larger database with better data quality. The fast method allowed us to measure various engine types during their post-overhaul test runs with short test points. We also performed effective density measurements during two dedicated test campaigns of the same engine. These campaigns investigated the effects of an alternative fuel blend on emissions and the evolution of the exhaust plume downstream of the engine exit plane. In the latter campaign, the effective density was measured with and without the treatment with a catalytic stripper approximately 25 m downstream of the engine exit plane.

Figure 1 shows the compiled results obtained for all engines and fuels tested with exhaust samples taken at the engine exit plane and 25 m downstream with a catalytic stripper. The results confirm the thrust dependence of the effective density distributions reported previously. The most distinct differences are between the effective density distributions at idle thrust (Figure 1, a) and medium to high thrust (Figure 1, b). This trend was qualitatively the same for all engines tested. In contrast to our previous report, the effective densities at medium and high thrust did not follow the mass-mobility relationship determined previously. The best fit of the data is an exponential function.

The fit functions determined have potential applications in aircraft PM emissions modeling and measurement. The size-dependent densities can be used to estimate PM mass concentration from particle size distributions measured using mobility particle sizers. The density functions can be used to improve particle loss correction models in sampling systems for aircraft engine emissions.

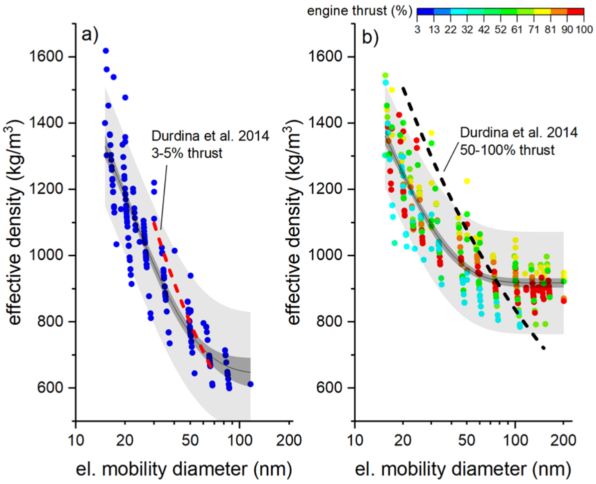

Figure 1. Effective density distributions of commercial aircraft turbine engines at low (a) and high (b) thrust with exponential fit functions. The light and dark gray areas are the 95% prediction bands and confidence bands.

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References

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