Aircraft Gas Turbine Non-Volatile Particle Mass and Number Emissions Measured With an AIR 6241 Compliant System

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Aircraft PM emissions have been limited since 1981 and measured by means of the metric filter smoke number (FSN) using an undiluted heated sampling system. The regulation has been effective in eliminating visible smoke around airports.

Now, a new metric is sought to better characterize the invisible particle matter (PM) emissions. This metric is needed to understand and better quantify the effects of PM emissions on health and climate change. So the mass and number of particle emissions originating from turbines are to be quantified with a more sophisticated sampling and measurement system. The Aerospace Information Report (AIR 6421) [1] defines the measurement protocol. Its hallmarks are an early dilution and cooling of the sample, well-defined set sample flows as well as tubing lengths and diameters.

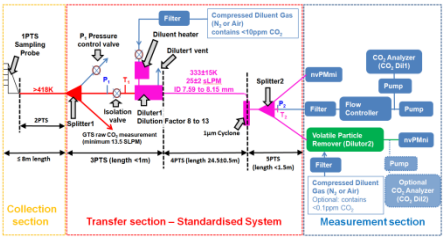

Figure 1: Schematic of particle measurement system acc. to AIR6241 [1]

Prototypes of this AIR compliant system have been developed, tested, and results have been published.

Now the first commercial version is available from AVL.

AVL Sampling System for Aviation

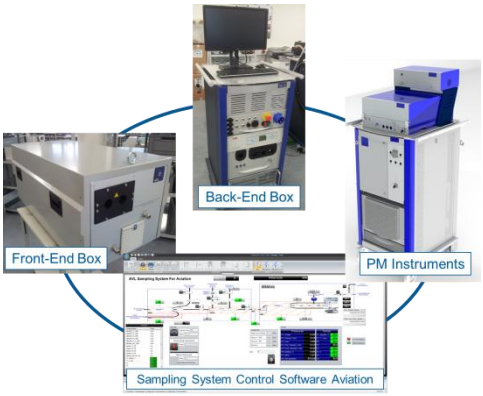

Figure 2: AVL Sampling System for Aviation

Measurement Results

Particle Number (PN) correlation measurements have been conducted and show excellent agreement compared to the research reference system for an engine exhaust (Fig. 3).

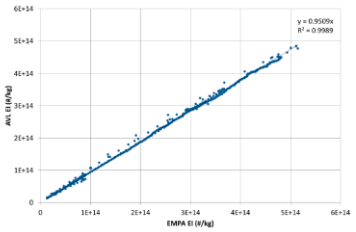

Figure 3: Correlation of AVL system to reference system on number

Measurements on a J-85 turbojet engine during commissioning of the AVL sampling system and instrumentation at UTSI in Tullahoma are shown in Fig. 4.

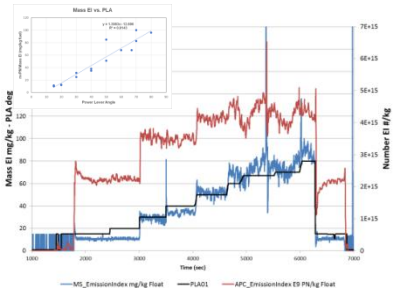

Figure 4: System Commissioning J-85 Emission Indices

The results are consistent with the measurements of late 80's engine technology reported by EMPA [3].

The new system makes it possible to obtain better estimates of actual engine-out emissions. The simultaneous measurement of particle mass and number possible with this system, gives qualitative information on particle size. This can be used to compensate for the size dependent particle losses internal to the sampling system, and provide for factors that can be used to adjust measurements to the engine-out values.

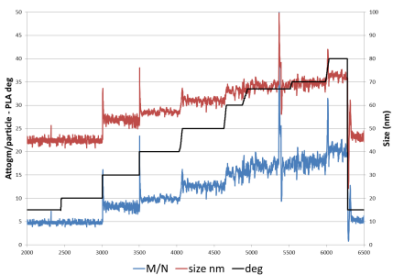

Figure 5: System Commissioning J-85 Size Estimates

The size information in Fig. 5 is the diameter of a water droplet that has the same average mass. This metric will be useful for estimates of particle losses in the sampling system, so that a more realistic engine-out mass and number can be estimated. The corrections are significant. Detail work for applying such corrections and its validation is on-going in the SAE E-31 committee. An approximate theoretical evaluation of the effects of these losses for log normal distributions is shown in Fig. 6. For the sizes expected in aircraft measurements, the adjustments are on the order of 50% for mass and a factor of 3 for number.

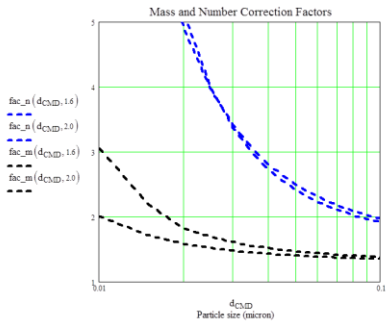

Figure 6: Mass and Number Correction Factors vs. CMD and GSD

Conclusion

The SAE E-31 committee's AIR6241 sampling protocol has been demonstrated and is now available in a commercialized version from AVL.

PM emission measurements correlate well with the proof of concept prototypes and are providing consistent measurements with the improved metric.

References

[1] Aerospace Information Report, AIR 6241

[2] T. Rindlisbacher, Non-volatile Particle Mass and Number Standard for Aircraft Gas Turbines, 17th ETH Conference on Compustion Generated Nanoparticles, 24th June 2013

[3] Benjamin Brem, Lukas Durdina und Jing Wang, Non-volatile PM Mass and Number Emissions of Aircraft Gas Turbine Sources, Air Quality and Particle Research Group, Empa Dübendorf, Institute of Environmental Engineering, ETH Zürich, 17th ETH Conference on Combustion Generated Particles, 24th June 2013

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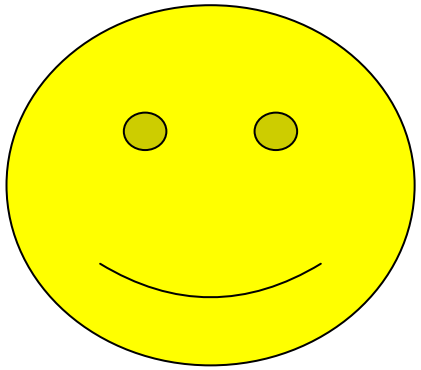

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