Characterisation of solid and semi-volatile gas-turbine particulate matter using a catalytic stripper

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Gas turbine particulate matter (GTPM) consists of solid and semi-volatile particles that originate from partially oxidised fuel and lubricating oils. Many techniques are available for measurement of particle number, size, and mass. However, often the volatile nature of these particles is not measured *a priori*. Advanced techniques are designed to respond to particles of a specific volatility or composition (such as solid, elemental carbon) but there are known cross-sensitivities. Catalytic stripper[1] (CS) technology provides an alternative method to aid in further elucidating the composition of an aerosol. A CS contains an oxidising catalyst that is used to fully remove the semi-volatile hydrocarbon particles and vapors in an exhaust gas stream. In this way, remaining particles are operationally defined as “solid.”

The primary objective of this study was to measure the solid and semi-volatile fractions present in GTPM using a catalytic stripper specifically designed for the “Sample III ” program that aimed to support SAE E-31 in drafting the Aerospace Recommended Practice (ARP) on the measurement of aircraft engine non-volatile particulate matter (nvPM) number emissions[2]. GTPM was generated by a GE CFM56-5B4-2P engine (120 kN, 27000 lb) with a dual annular combustor (DAC) is designed to minimise emissions, especially of NO_x, by optimising combustion for the different engine power modes and flight phases. Operating conditions were chosen to provide combinations of different levels of solid and semi-volatile material at modest power levels, thus minimising fuel consumption and allowing for more extensive testing.

Fig. 1 shows the sampling apparatus with raw gas turbine exhaust being sampled using 16 m transfer line heated to 160°C that is compliant with current regulations and a manifold to distribute the aerosol.

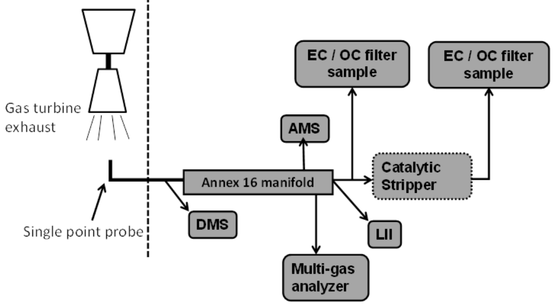

Figure 1. GTPM measurement apparatus for raw exhaust.

The primary evaluation metric reported on here is the EUSAAR “EC/OC” protocol that is used to define the concentration of elemental carbon. EC results were compared with laser induced incandescence (LII), which directly measures a related quantity, namely “black carbon.” The EC/OC method also classifies the amount of (semi-volatile) organic carbon present, and therefore enables estimates of the semi-volatile faction. Results are also compared with both gas analysis and an alternative method particle measurement, the centrifugal particle mass analyser (CPMA) used with and without a CS.

Fig. 2 shows results of EC/OC analysis upstream and downstream of the CS for various engine power conditions. Results upstream the CS show that the elemental carbon fraction of the PM varies from ~10% to 90%, whereas downstream the CS there is only elemental carbon. Thus, for all turbine conditions the CS removes all OC, which allows for parallel measurement of the solid fraction using any typical aerosol instrument.

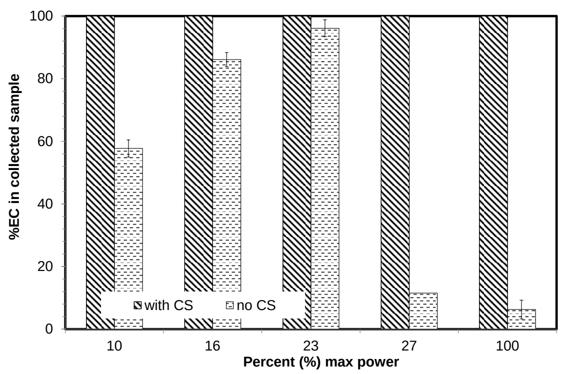

Figure 2. EC/OC results showing %EC in each sample collected up and downstream of the CS.

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[2]Crayford, A.; Johnson, M. SAMPLE III: Contribution to aircraft engine PM certification requirement and standard. Second Specific Contract– Final Report. *EASA.2010.FC.10 Specific Contract No: SC02*.