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Optical properties of soot particles emitted by standard and alternative aviation fuels

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Introduction

The replacement of standard aviation fuel with alternative fuels is a sustainable solution within the aviation sector where the legislation for emissions is imposing lower values while the energy conversion output is kept to 99.9 %. These quests are resulting in instable combustion conditions for the airplane engines due to the low global richness of the flame during the cruise running condition. The development of experimental techniques which are able to correctly quantify and detect biofuel emissions in combustion conditions certified for aviation needs is this way deemed necessary.

Methods

Large scale engine or representative test rig condition runs are technically and economically challenging, therefore laboratory tests are exploited. A Combustion Aerosol STandard generator (CAST) designed to burn aeronautic fuel and dedicated to study the emissions after the combustion of Jet A-1 kerosene and synthetic paraffinic kerosene (SPK) is tested in atmospheric combustion conditions at three oxidation airflow settings for each fuel. The CAST exhaust is monitored with a multitude of techniques which give information on the physico-chemical properties of particulates and other combustion induced pollutants. Therefore two complementary laser induced incandescence (LII) systems (custom-built and commercial) were used for the evaluation of soot emissions and mass spectrometry was used to study the chemical composition of non-volatile particulate matter (nvPM), semi-volatile particulate matter (svPM) and volatile particulate matter (vPM). A condensation particle counter (CPC) was used to obtain the particle number, a scanning mobility particle sizer (SMPS) was used to measure the particle size distributions and gas detectors were used to monitor the CO/CO₂ and SO₂ values. The emitted PM was characterized with two mass spectrometry techniques which linked the optical properties of the emissions to their chemical composition function of the experimental configuration and the combustion conditions. The partition between the vPM, svPM and nvPM was possible by using catalytic stripper (CS) systems on the exhaust stream and by the sampling method of particulates on successive quartz

fiber filters (bare and coated with trapping black carbon layers for the gas-phase emissions).

Conclusions

Differences were induced in the bulk and physico-chemical properties of the exhaust when changing the fuel and the combustion conditions. It was observed that particles with different organic contents absorbed distinctly the laser radiation and therefore it was possible to obtain an indirect indicator (given by the analytical techniques) on the optical properties of emissions at different working conditions. The use of a CS proved efficient in removing the svPM from the Jet A-1 emissions (Figure 1) but significant differences were measured for SPK emissions where the sublimation threshold was reached at higher laser fluences. Approximately all the results of the commercial instruments (CPC, SMPS, LII and PPS) were biased by a high content of vPM and svPM on the exhaust. Furthermore bulk (absorption properties) and surface (detailed chemical composition) properties helped in understanding these deviations and led to a proper quantification of vPM and nvPM for emissions characteristic of standard and alternative aviation fuels.

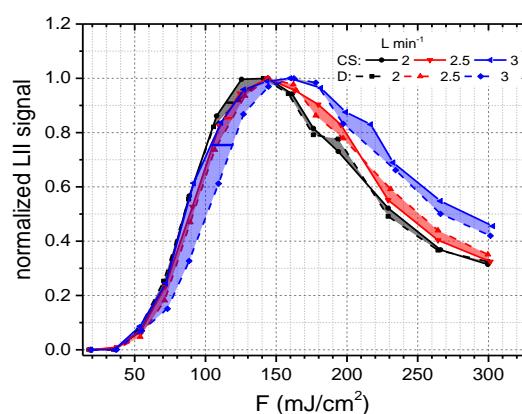


Figure 1. The variation of the LII signal with the laser fluence (*fluence curves*) for emissions of Jet A-1 fuel. Data obtained with the custom built LII system in direct (D) and treated exhaust with a CS at three oxidation airflows: 2, 2.5 and 3 L min⁻¹.

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