IMPACT DE LA COMPOSITION DU CARBURANT AÉRONAUTIQUE SUR SES ÉMISSIONS

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TITLE

Impact of aeronautic fuel composition on emissions

RESUME

L'aviation est l'un des secteurs de transport en pleine croissance et cette tendance devrait se poursuivre dans les prochaines années. Par conséquent, l'impact des émissions de l'aviation sur le climat et la qualité de l'air est très préoccupant. Parmi les différentes options disponibles, l'industrie aéronautique a identifié le développement des biocarburants comme l'un des principaux outils permettant de lutter contre ses émissions. Dans ce travail, nous avons utilisé un générateur standard d'aérosol de combustion (CAST), spécialement conçu pour fonctionner avec un carburant liquide, afin de comparer les émissions d'un kérosène standard (Jet A-1) avec celles d'un kérosène paraffinique synthétique Fischer-Tropsch (FT-SPK).

ABSTRACT

Aviation is actually one of the strongest growing transport sectors, and this trend is predicted to continue. Therefore, there is a big concern linked to the impact of aviation emissions both in climate and air quality. Among the different options available, the aviation industry has identified the development of biofuels as one of the major tools to tackle its emissions. In this work we have used a combustion aerosol standard generator (CAST), specially designed to work with liquid fuel, to compare the emissions produced by a standard kerosene (Jet A-1) with those produced by a Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)

MOTS-CLES : Suie, biocarburant, émissions moteur / **KEYWORDS:** Soot, biofuel, aircraft engine emissions

1. INTRODUCTION

In the period up to 2030, global aviation is expected to grow by 5% annually according to the International Air Transport Association (IATA). Currently, aviation represents 2% of global CO_2 emissions, but is expected to grow up to 3% by 2050 (Lee et al. 2010). While this amount is small compared with other industry sectors, such as energy production and ground transport, these industries have viable alternative energy sources currently available. For example, the power generation industry can turn to wind, hydro, nuclear and solar technologies to produce electricity with low CO_2 emissions. In the case of aviation, while solar and electric aircrafts are being researched, they are still a long way from commercial versions due to aviation need for high power-to-weight ratio and globally compatible infrastructure. Therefore, the aviation industry has identified the development of biofuels as one of the major tools to tackle its emissions.

Aviation emissions are not limited to greenhouse gases like CO_2 or water but include as well other gases like nitrogen oxides (NO_x) or sulfur oxides (SO_x) and volatile and non-volatile particulate matter (vPM and nvPM respectively). nvPM is defined as particles present in the engine exhaust at temperatures higher than 350 °C and consists essentially in soot particles produced by the incomplete combustion of the fuel. vPM is formed by nucleation from gaseous precursors in the cooling exhaust gas downstream the combustor, when the concentration of preexisting particles has decreased, favoring homogeneous nucleation versus heterogeneous one (absorption of gases onto preexisting particles).

Currently there are five biofuel production pathways technically certified and 16 more certifications are in preparation (Mawhood et al. 2016). Complete engine tests required for testing these new generation biofuels are technically and economically challenging. In addition, the high fuel consumption (~ 600 L/min) and the low availability of biofuels impose strict time limits for these tests, thus systematic experiments beyond the standard certification purposes are rarely available.

In this work we have used a Combustion Aerosol STandard generator (CAST) specially designed to work with aeronautic fuel to study emissions from standard aviation kerosene (Jet A-1) and a biofuel, namely a Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK).

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2. EXPERIMENTAL SET-UP

The selected fuels were burned in a CAST generator (Jing Ltd) designed to work with liquid fuel. This generator is based on the design of mini-CAST, a well-known standard source of soot (Moore et al. 2014). In liquid CAST a propane flame is used to vaporize the liquid fuel that is then homogenized to generate a laminar diffusion flame. The main advantage of the CAST generator is the low fuel consumption (~100 µL/min). Emissions produced by CAST where characterized using a comprehensive set of instruments (Fig. 1).

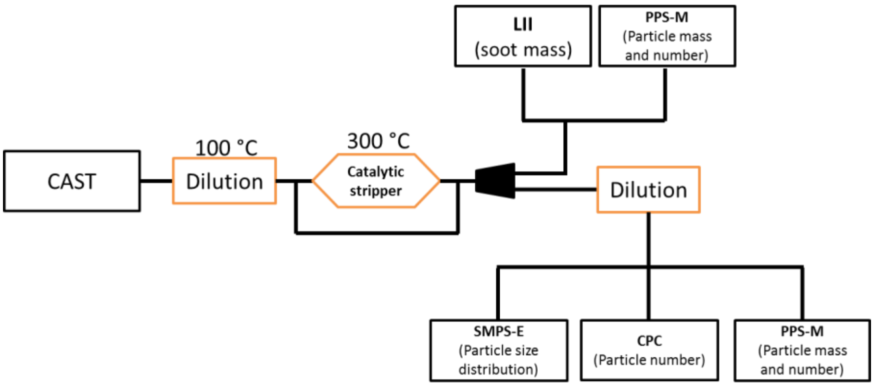

Figure 1. Experimental set-up scheme

The emission produced by CAST was first diluted using an ejector dilutor heated at 100 °C (DI-1000, Dekati Ltd) then the sample was either analyzed without any treatment, so nvPM and vPM where measured, or it was treated with a catalytic stripper heated at 300 °C to remove the vPM. Then the sample was split in three, one part was analyzed using Laser Induced Incandescence (LII, Artium Ltd) to measure soot mass. The second part was analyzed by a Pegasor Particle Sensor type M (PPS-M, Pegasor Ltd) to measure particle number and mass. The last part was again diluted by an ejector dilutor at room temperature (VKL, Palas Ltd). After dilution, the sample was analyzed by a Scanning Mobility Particle Spectrometer using a faraday cup electrometer as particle counter (SMPS-E, Grimm Ltd) to determine the particles size distribution, a Second PPS-M to determine particle number and mass, and by a Condensational Particle Counter (CPC, Grimm Ltd) to determine particle number.

All CAST parameters was kept constant except the oxidation air flow. The propane flow was set to 30 mL/min, because in this case the pilot flame does not produce any particles. Nitrogen quenching flow and dilution air flow were set to the default values defined by the fabricant (7 and 20 L/min respectively). Fuel flow was set to 100 µL/min. The oxidation air flow was varied between 2 and 4 L/min to evaluate the impact of different fuel to air ratios on emissions.

3. RESULTS AND DISCUSSION

Fig. 2 show the particle number measured by CPC for the different carburant studied, both for total PM and nvPM emitted. As can been seen, the use of FT-SPK reduces the total PM emitted between 27% and 59% compared to Jet A-1 and the nvPM emitted between 38% and 60%. These results are similar to those obtained with the PPS-M.

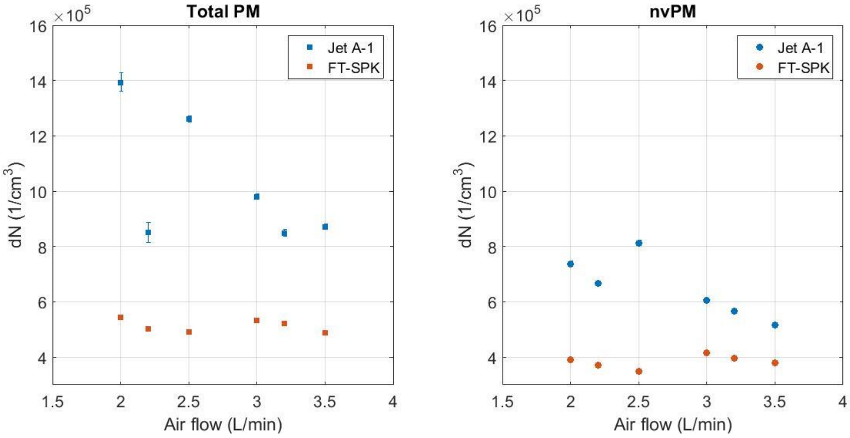

Figure 2. Particle number for total PM (left) and nvPM (right) measured with CPC for Jet-A& and FT-SPK

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Regarding the size of particles produced by both fuels, we found that FT-SPK produced smaller particles than Jet A-1 for all air flows, both for total PM and for nvPM. Fig. 3 shows an example of the size distributions for total PM for 2 L/min air flow case.

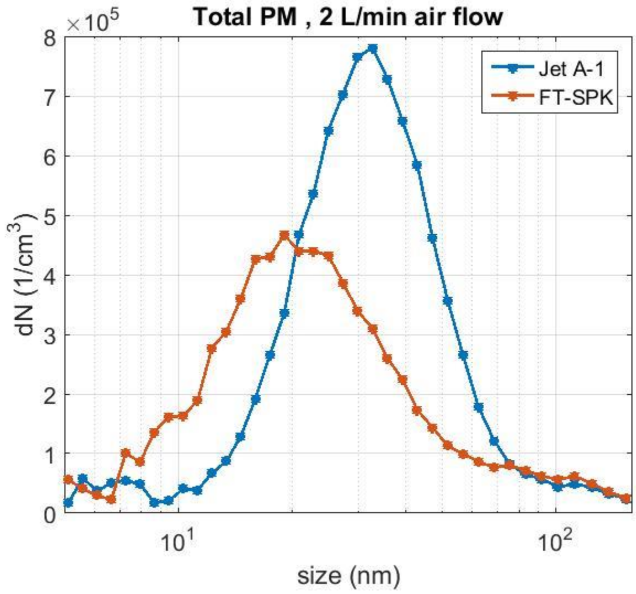

Figure 3. Size distribution of total PM produced by Jet A-1 (blue) and FT-SPK (red) for an air flow of 2L/min

Finally, if we look to the soot mass produced by the two fuels, we can see how FT-SPK produces less soot than Jet A-1 (Fig. 4). We can notice as well that there is a linear relation between the soot produced by Jet A-1 and FT-SPK for different air flows.

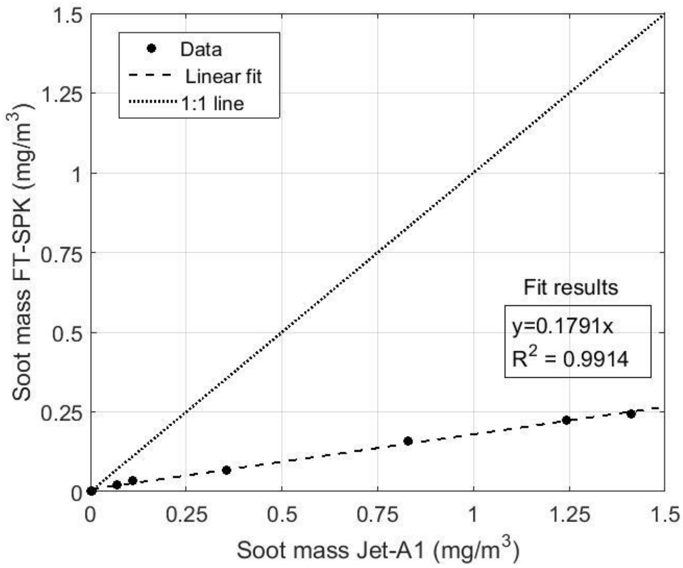

Figure 4. Soot mass produced by Jet A-1 compared to soot mass produced by FT-SPK

Our results show how FT-SPK produces less particles, both in mass and number concentration that Jet A-1. In addition we have found that FT-SPK produces smaller particles. Although these results are promising, this study should be completed by further work on different biofuels, and particularly on mixtures of Jet A-1 and biofuels certified for their use in aviation.

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Lee, D. S., et al. (2010) Atmos. Environ., 44, 4678-4734.
Mawhood, R., et al., (2016) Biofuels, Bioprod. Bioref. 10, 462-484.
Moore, R.H., et al. (2017) Scientific Data 4, 170198.

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