Chemical characterization of volatile organic compounds emitted by an aircraft turbine engine

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Aircraft emissions received increased attention recently because of the steady growth of aviation transport in the last decades. Aircraft engines substantially contribute to emissions of particulate matter and gaseous pollutants in the upper troposphere and in airport vicinities. These emissions have an impact on air quality and global warming.

A series of measurements were performed during the A-PRIDE 8 campaign in October 2015 at the aircraft engine testing facility of SR Technics, within the Zürich airport, Switzerland. The engine exhaust was sampled at the engine exit plane by a single-orifice probe. A wide range of instruments was connected to the common sampling line to determine physico-chemical characteristics of non-volatile particulate matter (nv-PM) (Durdina et al., 2014; Brem et al., 2015) and gaseous pollutants. One engine type (CFM56-7B26) was tested during this study. The conventional fuel Jet A-1 was used as the base fuel, and experiments were performed with the base fuel doped with two different aromatic solutions (Solvesso 150 and naphthalene depleted Solvesso 150).

During this presentation, we will show results obtained for volatile organic compounds (VOCs). VOCs were sampled with 3 different adsorbing cartridges, and analysed either by thermal desorption gas chromatography/mass spectrometry (TD-GC/MS, for Tenax TA and Carboxen 569), or by high performance liquid chromatography (HPLC, for DNPH). The use of 3 different sorbents allowed the measurement of a wide range of compounds, such as short- and long-chain alkanes, aromatics, and oxygenated compounds. The total VOCs concentration was also measured with a flame ionization detector (FID), but without any information on the chemical speciation. In addition, fuel samples were also analysed by GC/MS, and their chemical composition was compared to the VOCs emitted via engine exhaust.

The total VOCs concentration was much higher at ground idle (4-7% thrust, >200 ppm C) than at high thrust (<3 ppm C during take-off, 100% thrust). This result may be due to lower temperature and poorer air/fuel mixing in the primary combustion zone, and lower fuel/air equivalence ratio at low thrust. All the VOCs identified with the Tenax TA and Carboxen 569 cartridges were either alkanes or aromatics. The most concentrated compounds were small molecules (C3-C7) from the following families: alkenes, alkanes, oxygenated compounds and small aromatics.

The comparison between the chemical composition of fuel samples and VOCs emitted by the aircraft engine showed significant differences. Fuel samples were dominated by alkanes (Figure 1, left), whereas VOCs emitted by the aircraft engine were mainly comprised of alkenes and oxygenated compounds (Figure 1, middle). We also noticed some significant differences in the aromatic fraction between the fuel and the exhaust. C2-, C3-, and C4-benzenes were significantly present in the fuel but only traces of these compounds were present in the exhaust, while benzene and toluene were observed only in the exhaust (Figure 1). This result may be due to dealkylation reaction during combustion in the engine. We also observed an important effect of the thrust level on the composition of VOCs. Indeed, at high thrust, VOCs were totally dominated by oxygenated compounds, following a higher combustion efficiency. The effect of the fuel aromatic content on the VOCs emitted by the engine will also be discussed.

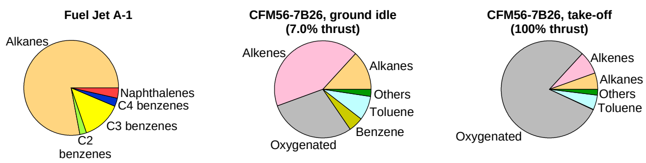

Figure 1. Left: composition of the fuel Jet A-1. Middle: composition of VOCs at 7% thrust (ground idle). Right: composition of VOCs at 100% thrust (take-off).

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