UNREAL Project: Unveiling nucleation mechanism in aircraft engine exhaust and its link with fuel composition

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Introduction

Aviation emissions are not limited to greenhouse gases like CO_2 or water but include as well other gases like nitrogen oxides (NOx) or sulfur oxides (SOx) 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). Sulfuric acid formed in the engine exhaust seems to be linked to the formation of vPM. However, the amount of sulfur present in the fuel converted to sulfuric acid in the exhaust is too small to explain the amount of vPM observed. Chemi-ions and organic compounds emitted by the engine are one of the most suitable candidates to explain the formation of vPM in the engine exhaust, but the molecular mechanism behind this phenomenon is still unknown.

The main objectives of this project are:

1) To determine the mechanism behind vPM formation in the engine exhaust and if there is a link with fuel composition

2) To establish a sampling protocol for vPM measurements that can be used in certification processes

3) To determine the impact of fuel chemical composition on the physico-chemical properties of vPM and nvPM

Within this project we plan to use the state-of-the-art Combustion Aerosol Standard (CAST) generator especially designed to work with aeronautic fuels available at ONERA as emission source. To study the formation of vPM in detail, we will use the atmospheric chamber CESAM available at LISA and a Potential Aerosol Mass flow Reactor (PAM) available at LSCE and operated in collaboration with INERIS to induce the formation of vPM from the exhaust of CAST. We will use the experimental means available at ONERA and CESAM to characterize the emissions. In addition, key chemical characterization will be performed by SAGE and PhLAM. To get further insight into the molecular mechanism behind vPM formation, we will perform a series of theoretical simulations led by UTINAM. To complement the consortium, two foreign partners will join as well: Tampere University of Technology (TUT), that will participate in the characterization of molecular clusters emitted by CAST though the Atmospheric Pressure Interface Time of Flight Mass spectrometry (API-toF), and the Spanish national institute for aerospace (INTA) that will collaborate offering its sampling line in the stack of their test bench to measure vPM formation in one of its standard measurement campaigns with a complete engine.

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