Comparison of non-CO_2 Turboshaft Engine Emissions using Jet A-1, HEFA- and FT-SPK

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Introduction

Why are Sustainable Aviation Fuels (SAF) important?

- The aviation sector agreed to be CO_2 neutral until 2050[1]. While aircraft fleets will be gradually replaced or modernized, a portion of today's aircraft and engines will likely still be in operation by 2050, as the transition to alternative propulsion technologies progresses more slowly than in other sectors
- SAF, if they are sustainable, can have a big impact on CO_2 lifecycle
- Gas turbine engines emit CO_2, H_2O, CO, UHC, NO_x, VOC, particles (vPM and nvPM) and other emissions (direct and indirect emissions) - alternative fuels / SAF are known to reduce some of these emissions

[1] ATAG. Beginner's Guide to Sustainable Aviation Fuel. April 2023.

Are SAF a „new“ possibility to improve CO_2 & non-CO_2 emissions?

- SAFs are not entirely new, as early studies - such as NASA APEX (2005) or AAFEX (2011) campaigns - already demonstrated their potential to reduce non-CO_2 emissions
- Other campaigns lead to comparable conclusions - alternative fuels (including SAF) can reduce nvPM mass and number concentrations
- ReFuelEU - from 2025 to 2050 its mandatory to blend conventionel Jet A-1 with SAF

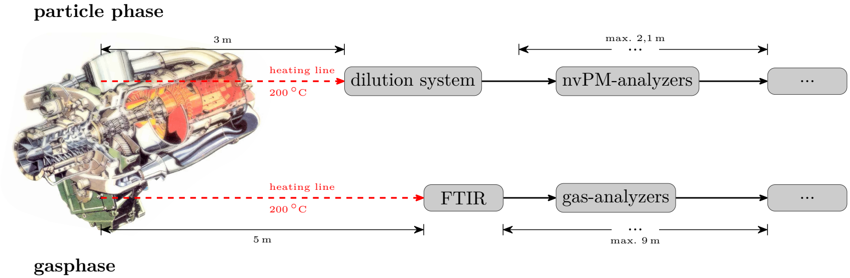
Motivation

Regulated and non-regulated aircraft engines

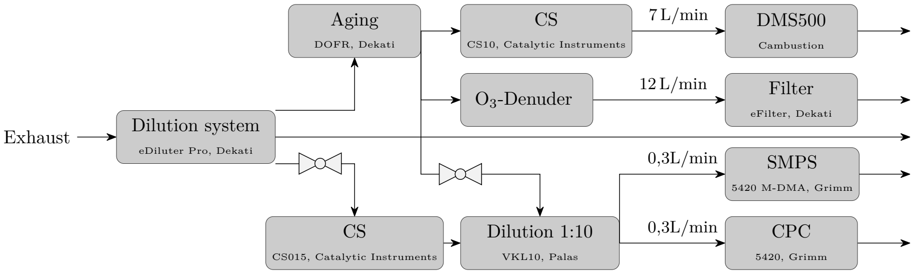
- The ICAO Annex 16 Vol. II regulates gaseous and nvPM emissions of turbojet and turbofan engines ($F_{00} \geq 26{,}7\,\mathrm{kN}$)
- Turboshaft engines for helicopters, turboprop or small turbofan and turbojet engines are **not regulated** - these aircrafts can have a high impact on local air quality (LAQ) - especially during ground operation
- There is no official and public available database for non-regulated engines

Setup

Overall experimental setup (2022 - 2024)



Experimental particle meassurement setup 2024



Fuels

Results

- Different reduction potentials for CO and UHC
- FT-SPK shows a more significant impact on both emission components
- There were no significant changes in EI_{NOx} between the fuels used

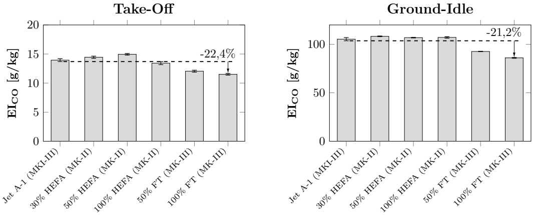


Fig. 1: EI_{CO}

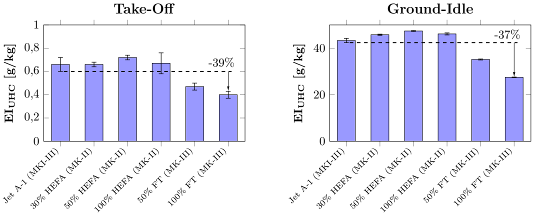


Fig. 2: EI_{UHC}

- Aromatic compounds (particle precoursors) and their derivatives were also reduced significantly

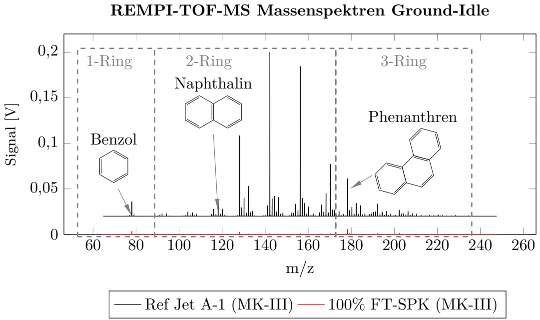


Fig. 3: Mass spectrograms for aromatic compounds

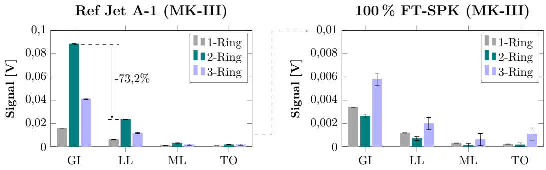


Fig. 4: Reductions for aromatic compounds

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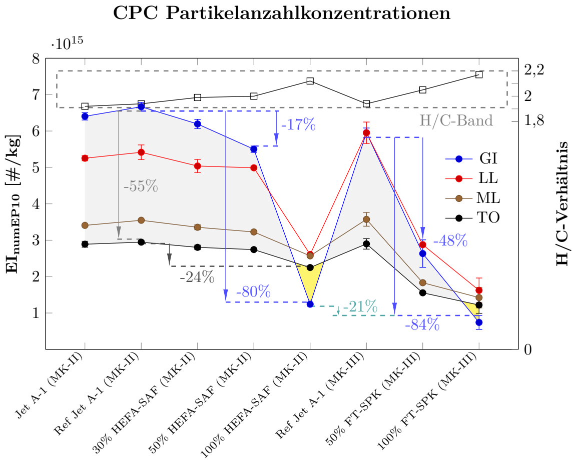

Fig. 5: $EI_{numEP10}$

- nvPM number concentrations show the highest reduction potential for neat SAF/SPK
- Reversal of the load point-dependent emission behavior at 100% SAF/SPK ($EI_{numEP10}$ differs between GI and TO)

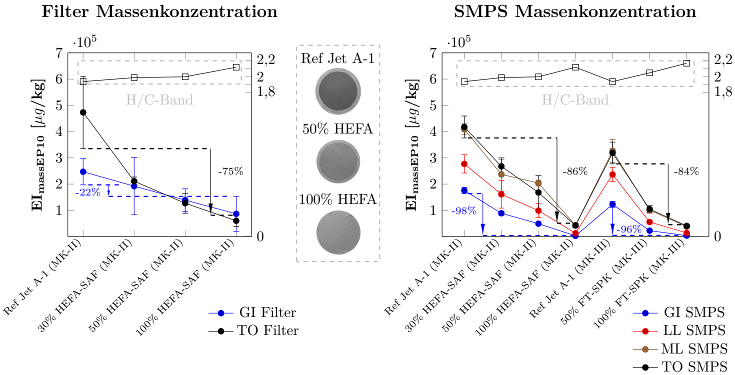

Fig. 6: $EI_{massEP10}$

- $EI_{massEP10}$ is higher in TO than in GI due to higher fuel-flow and the fuel rich combustion zone of the Allison 250-C20B
- $EI_{massEP10}$ can be reduced up to 84% (TO) and 98% (GI) by using HEFA- and FT-SPK

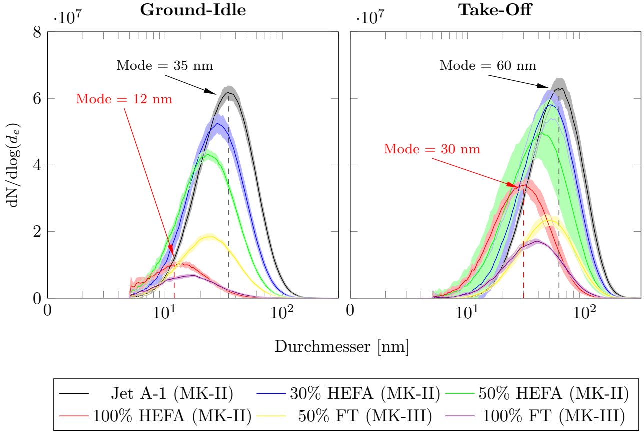

Fig. 7: PNSDs

- Reductions for $EI_{numEP10}$ and $EI_{massEP10}$ can be seen in the PNSD of the fuels used
- the GMD is changing as a function of: **engine load** and **fuels used**

Summary & Outlook

- FT-SPK can reduce UHC- and CO-Emissions unlike HEFA-SPK - this could be attributed to the length of the hydrocarbon molecules and/or to physical fuel properties (boiling curves, viscosity) and influences on atomization
- HEFA- and FT-SPK-Blends (30% and 50%) show a reduction in nvPM number and mass - However, the biggest reduction potential can be seen with neat SPK
- Using alternative fuels shifts the soot particle diameter