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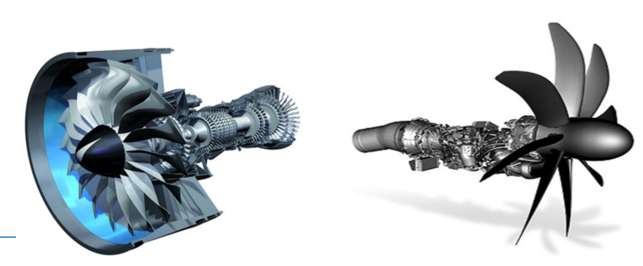

Particulate and Gaseous Emissions of an Allison 250-C20B Turboshaft Engine using FT-SPK

Introduction and Test Rig

Introduction

- **SAFs for Reducing Aviation Emissions:**
  Sustainable Aviation Fuels (SAFs), such as HEFA-SPK and FT-SPK, offer reduced CO_2 and soot emissions due to their low aromatic content.
- **FT-SPK and its Potential:**
  FT-SPK, a Power-to-Liquid (PtL) fuel, can achieve up to 99% GHG reduction with sustainable production, minimising land and feedstock challenges.
- **Study Highlights – FT 50 and FT 100:**
  This study uses advanced measurement systems to analyse FT-SPK (50% blend FT 50 and 100% neat FT 100) for emissions reduction and compares results to previous HEFA-SPK studies.

Allison 250-C20B Test Rig

Tab. 1 Allison 250-C20B technical data

Properties	Units	Values
Weight	kg	72
Length	mm	986
Width	mm	483
Heigth	mm	597
Max. power	kW	313
Max. air intake	kg/s	1.56
Max. pressure ratio	-	7.1
Power shaft rpm (100%)	1/min	6016
Gas generator rpm (100%)	1/min	50970
Power turbine rpm (100%)	1/min	33290

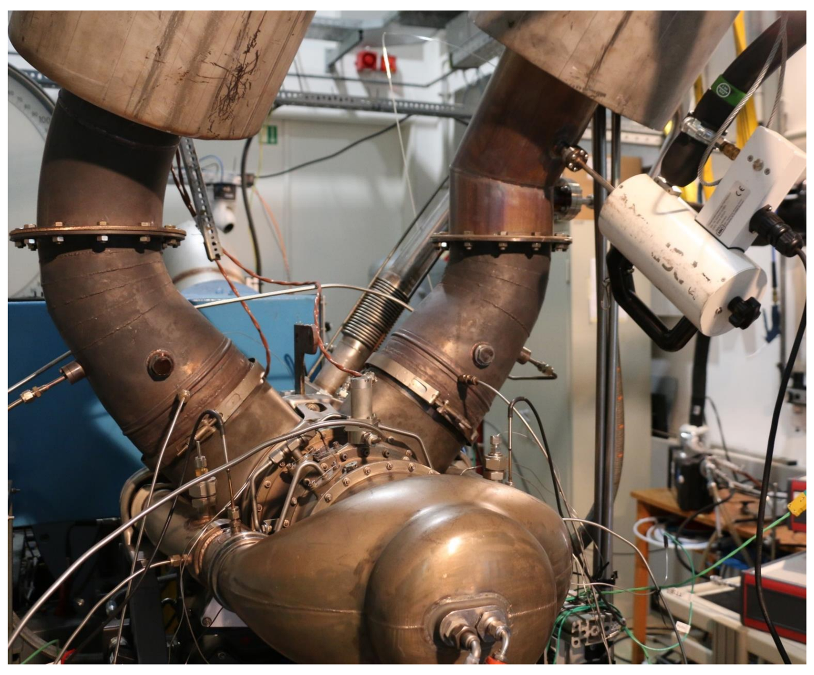

Fig. 1 Allison 250-C20B test rig

Methodology

Experimental Setup and Calculation

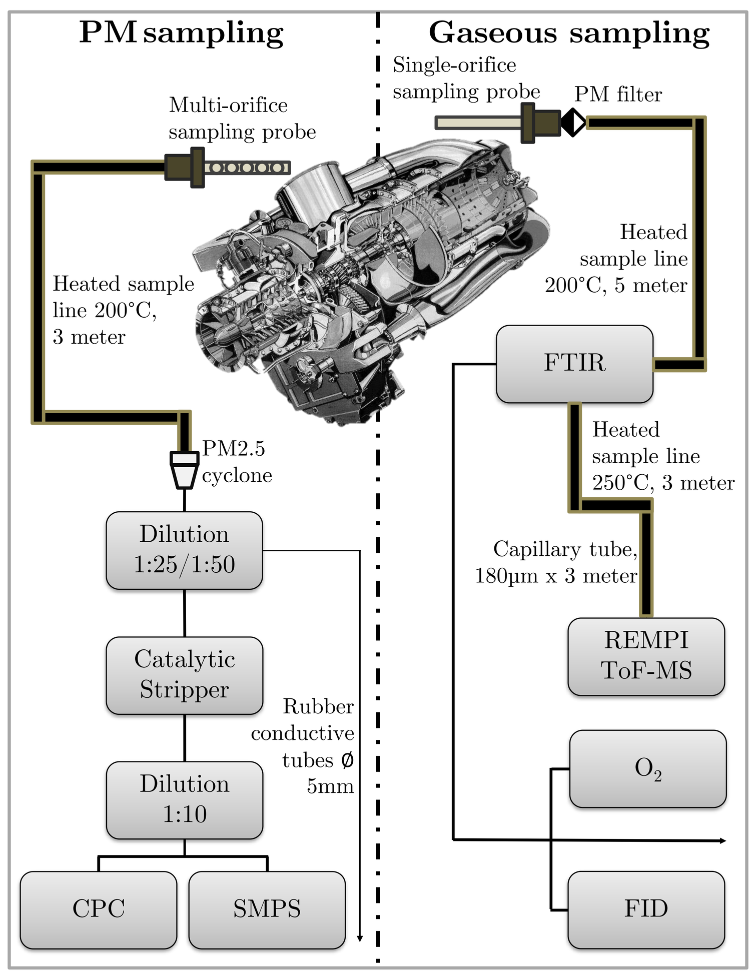

Fig. 2 Measurement setup

- **Emission indices (EI_x)** for CO_2, CO, NO_x, UHC, and PM number and mass are calculated following ICAO Environmental Protection - Volume II - Annex 16 and SAE ARP 1533C standards.
- **Gaseous emissions** are measured using FTIR, FID, O_2 sensors, and a REMPI ToF-MS.
- **Particulate emissions** are measured employing CPC and SMPS.

Fuels

Tab. 2 Fuel properties.

Properties	Method	Unit	Jet		50% SPK		100% SPK	
			Jet 24	Jet 23	FT	HEFA	FT	HEFA
Total Aromatics	ASTM D6379 :2021	vol%	17.0	15.8	8.9	7.9	0.11	<0.2
Naphtalenes	ASTM D1840 :2007	vol%	0.63	0.8	0.32	0.4	0.00	0.00
Total sulfur	ASTM D5453 :2019*	wt%	0.06	0.09*	0.03	0.04*	0.00	<0.0001*
Density at 15 °C	ASTM D4052 :2022	kg/m^3	793.3	799.3	775.4	785.5	757.0	771.8
Net heat of combustion	ASTM D4809 :2018	MJ/kg	43.4	43.1	43.6	43.5	43.9	44.0
Smoke point	ASTM D1322 :2022	mm	26.0	24.3	32.0	34.3	42.0	>45
Hydrogen content	ASTM D5291 :2021	wt%	14.00	14.01	14.70	14.57	15.40	15.10

- **FT-SPK:** nearly zero aromatics (including naphthalenes) and no sulfur, with a higher hydrogen content, lower density, higher net heat of combustion, and a significantly higher smoke point than conventional Jet A-1.
- **HEFA-SPK:** slightly lower hydrogen content and higher density than FT-SPK, indicating a lower proportion of n-alkanes and iso-alkanes.

Results

Particulate Emissions

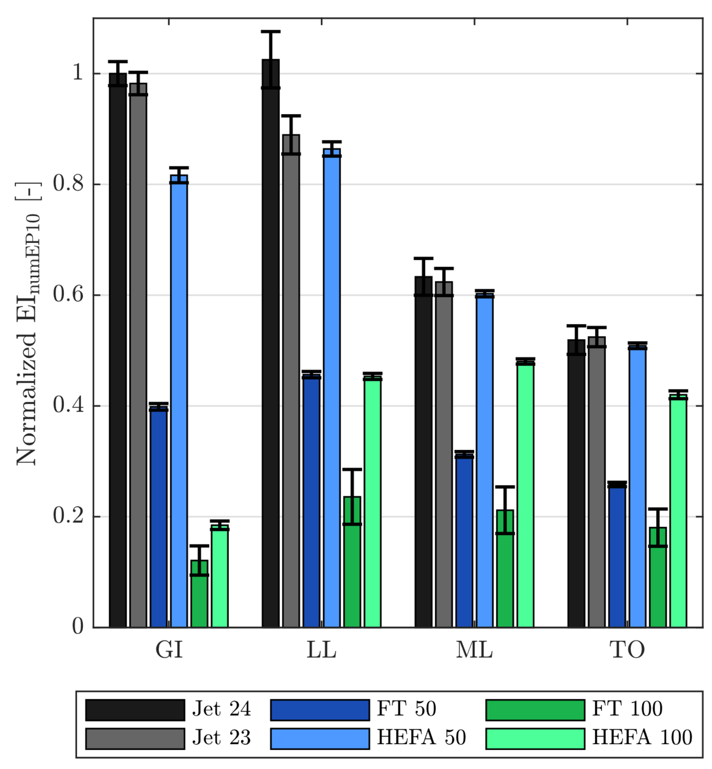

Fig. 3 Figure description.

- **Particle reductions** using FT-SPK compared to Jet 24 are significant, with the highest reductions at lower power settings (-88%).
- **The reduced sooting tendency** of FT-SPK is linked to its lack of aromatics, particularly naphthalene.
- **Larger particle reduction for FT-SPK** than HEFA-SPK at all blending levels
- **Small FT-SPK blends** can effectively lower emissions, while HEFA-SPK benefits most at high blending ratios.

Gaseous Emissions

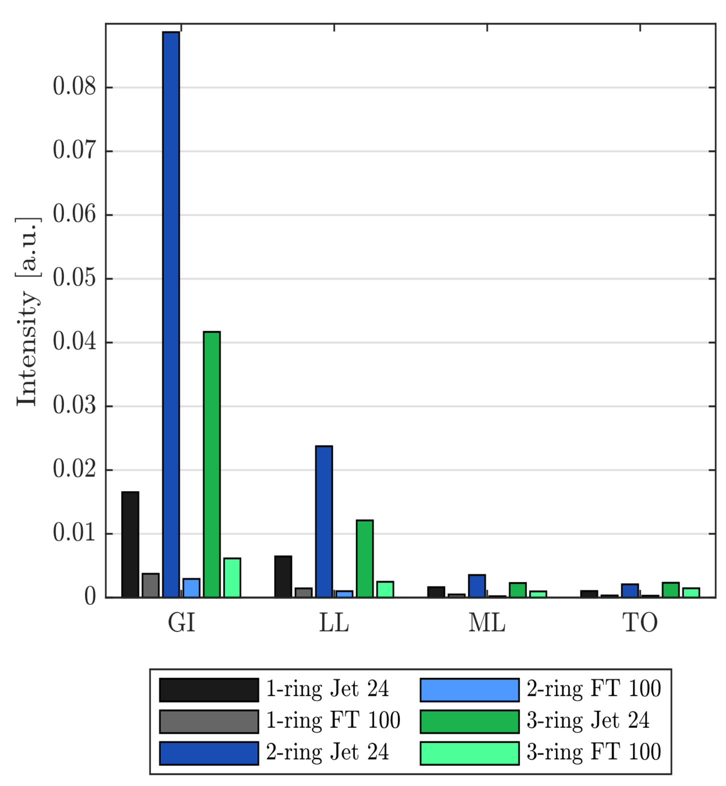

Fig. 4 Figure description.

- **Benzene, naphthalene and phenanthrene** are examined in Jet 24 and FT 100 across different power settings.
- **1-, 2-, and 3-ring aromatics** are reduced in FT 100 compared to Jet 24, with the highest reductions at lower power settings (up to −97% for 2-ring aromatics).
- **Aromatic reduction** aligns with particle reduction data, but only gas-phase aromatics were analysed, requiring further VOC-GC data for a complete assessment.

Gaseous Emissions

- **Expected emission reduction** for combustion byproducts at higher power settings.
- **CO_2 emissions at GI remain stable for FT-SPK**, while combustion byproducts CO (-11%) and UHC (-29%) decrease, suggesting more complete combustion and improved combustion efficiency. This effect cannot be seen for HEFA-SPK.
- **NOx levels increase slightly at higher power** settings for both SPKs but remain within error margins. FT-SPK shows a Nox reduction at GI, though the cause is unclear.
- **Differences between the two Jet A-1 fuels** likely stem from ambient conditions rather than fuel properties.

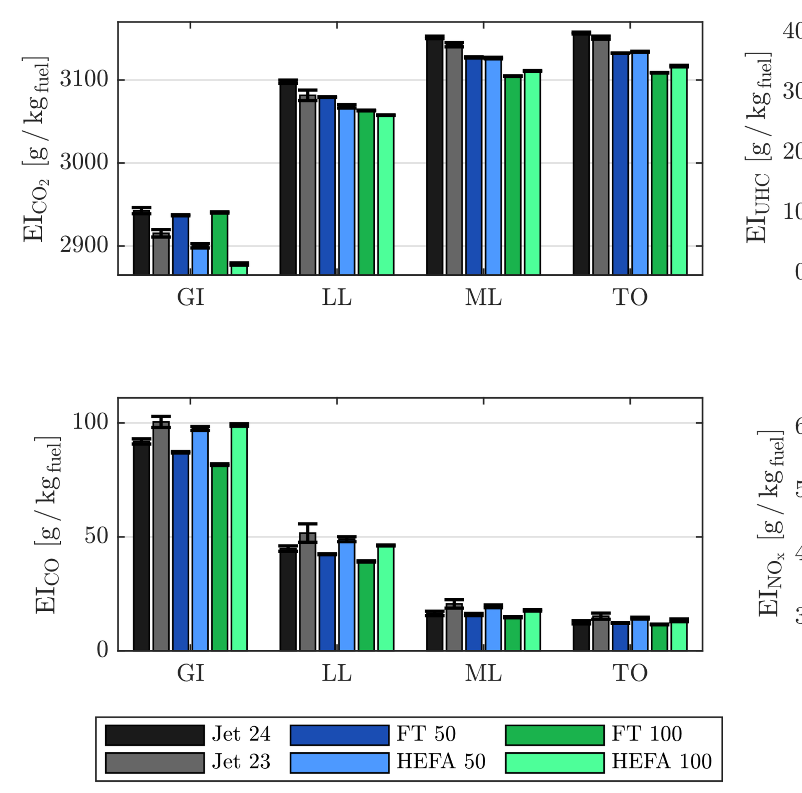

Fig. 5 Figure description.

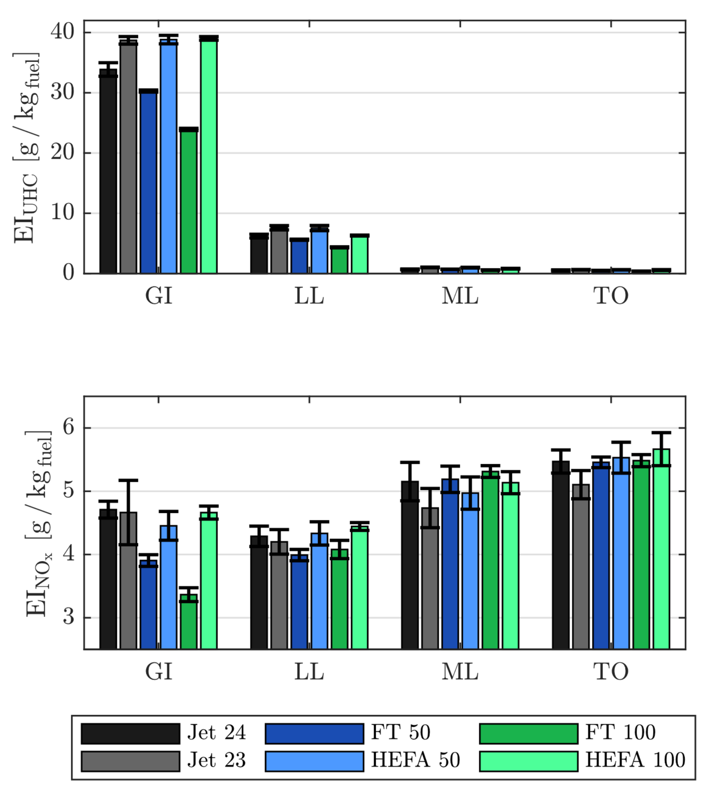

Fig. 6 Figure description.

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