Nanoparticle Emissions of a Flight Gas Turbine running Jet A-1 and GTL Mixtures

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Due to the limited resources of petroleum, alternative aviation fuel sources are in focus. One option is “Gas to Liquid” fuel (GTL). GTL is made from natural gas in a Fischer Tropsch process. GTL has no aromatic compounds and no sulfur. Compared to standard JET A-1, the hydrogen content of GTL is higher and density is lower. Due to the different fuel composition of GTL and JET A-1, combustion characteristics might be different. Therefore tests like described here are necessary to demonstrate that the use of GTL is possible without any problems.

A Cessna Citation II powered with Pratt and Whitney turbofan engines (P&W Canada JT15D-4) has been used for engine ground tests at Schiphol airport, Amsterdam. This was done in preparation of a flight test program. The Cessna is jointly owned by the Delft University of Technology and the Dutch National Aerospace Laboratory (NLR). The tested fuels are two different Jet A-1 base fuels and mixtures of these Jet A-1 base fuels with 10%, 20%, 30% and 50% “Gas to Liquid” (GTL) fuel. The GTL fuel is a Fischer –Tropsch synthetic paraffinic kerosene (FT-SPK) with no aromatic compounds. The international jet fuel specifications allow up to 50% volume SPK in Jet A-1, as long as a minimum of 8% volume aromatics are in the resulting mixture and all other “Table1” criteria are met.

The power settings used are the ICAO LTO points: TAXI, APPROACH, CLIMB, TAKE-OFF plus an additional “CRUISE” point. This corresponds to 7%, 30%, 85%, 100% and 65% thrust. The thrust level was controlled via the rpm of the engine.

The experimental setup was an area averaging probe, positioned at half an engine exit diameter behind the engine exit, followed by a 4.5 m heated sampling line, two diluters, EEPS (Engine Exhaust Particle Sizer) and FT-IR. The measured species are: CO, CO_2, NO, NO_2, SO_2 as well as particle size distributions and number concentrations. Due to the known fuel composition, so called emission indices EI are calculated as mg/kg burned fuel.

At all power settings, the emission indices for particles (mass and number) are significantly reduced by increasing the GTL content. Particle diameters are also reduced by increasing GTL content. For gaseous emissions a minor improvement was found for most test points by increasing GTL. A final engine inspection showed no harm to engine components.

ICAO - International Civil Aviation Organization

LTO – Landing and Take Off cycle

Institute of
Combustion Technology

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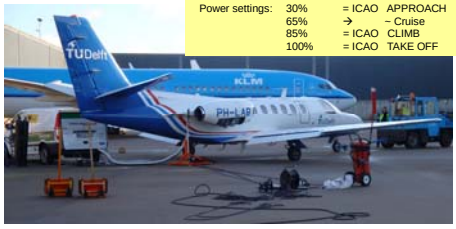
On wing ground engine tests: Compairing Gas to Liquide (GTL) Fuel vs Jet A-1

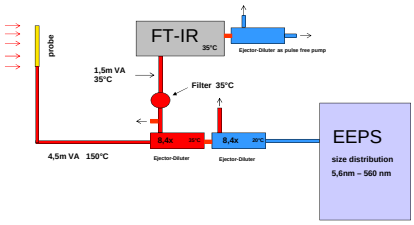
Power settings:

7% thrust	= ICAO	IDLE
30%	= ICAO	APPROACH
65%	→	~ Cruise
85%	= ICAO	CLIMB
100%	= ICAO	TAKE OFF



Cessna Citation / Pratt & Whitney turbofan engine **P&WC JT15D-4**

Experimental Setup



Base Fuel Composition

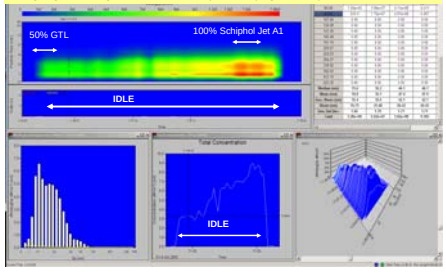
	Jet A-1	GTL	Jet A-1	Jet A-1
	Standard Kerosene	Gas to Liquide	hydroprocessed	Standard Kerosene
	base 2 FJ 2011		base 3 FJ 2011	base 1 2009
Carbon (%)	85,4	83,9	84,8	86,24
Hydrogen(%)	13,6	15,7	13,6	13,76
Ratio	1,9	2,2	1,9	1,9
aromatics	typical	zero	high	typical
sulfur	typical	zero	ultra low	typical
density	typical	low	high	typical

Fuel Blends

Base 2 + 10% / 20% / 30% / 50%vol GTL (Test 2011)
Base 3 + 10% / 20% / 30% / 50%vol GTL (Test 2011)
Base 1 + 10% / 20% / 30% / 50%vol GTL (Test 2009)

Due to the known carbon content of all fuels, Emission Indices EI in[mg/kg burned fuel] can be calculated

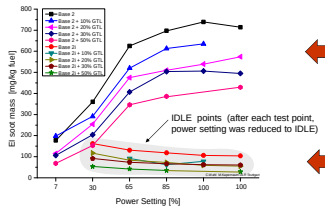
"Online Fuel Change"
Switching from **50% GTL** / base1 (right wing tank) to **100% Jet A-1** (left wing tank) during engine running at IDLE condition. (First campaign in 2009)



EI's: Standard Jet A-1 and up to 50%vol GTL (2011)

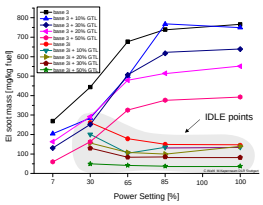
EI's: Hydroprocessed Jet A-1 and up to 50%vol GTL (2011)

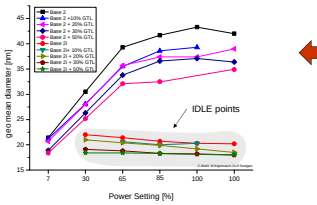
Results



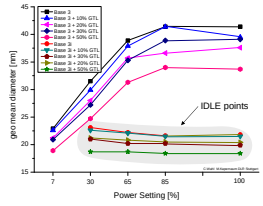
EI soot mass: Signifikant reduction by increasing GTL content at all power settings

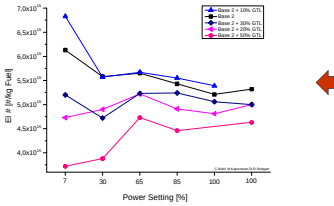
IDLE emissions degree with increasing engine temperature



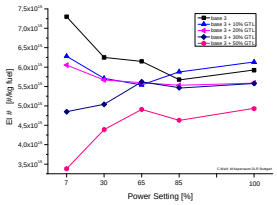


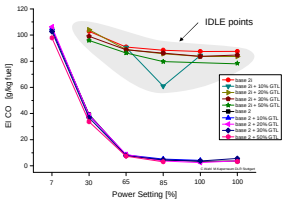
Geometric mean diameter: reduction at all power settings by increasing GTL content





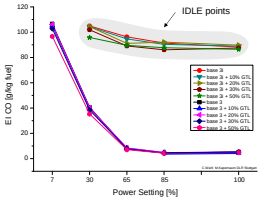
EI # Particle number: Reduction at most power settings by increasing GTL content





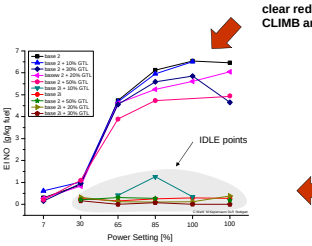
EI CO: Only minor reduction at IDLE power settings by increasing GTL content

EI CO: no GTL effect by incresing power setting

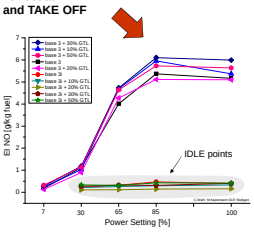


EI NO: clear reduction at CLIMB and TAKE OFF

EI NO: random effect at CLIMB and TAKE OFF



EI NO: at IDLE and APPROACH no effect for both base fuels



Conclusion:

- Increasing **GTL** content results in a **significant reduction in particle emissions** like soot mass, particle number and particle diameter for all power settings.
- Increasing **GTL** content show a **minor improvement in gaseous emissions** for some test points.
  (**CO** for both fuels but only at IDLE, **NO** only for base2 fuel mixtures at CLIMB and TAKE OFF)
- Final engine inspection showed **no harm to engine components**

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