Comparison of Nanoparticle Formation caused by leaded and unleaded Aviation Gasoline Combustion

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Keywords: Nanoparticle, soot emissions, aircraft piston engines, AVGAS 100 LL, AVGAS 91/96 UL

It is well known that combustion of kerosene or diesel can form soot nanoparticles. In this work it is shown, that gasoline powered piston engines can also emit nanoparticles.
(It is recommended from the piston engine manufacturer to run the piston engine under fuel rich conditions in order to keep engine temperatures low.)
Particle number concentration and particles size distribution are measured behind two small aircraft piston engines. The two flight piston engines were both powered with AVGAS 100 LL and AVGAS 91/96 UL.

AVGAS 100 LL is the standard leaded flight gasoline with a maximum of 560 mg lead per liter.
The AVGAS 91/96 UL is a special unleaded and environmental friendly AVGAS (not a MOGAS!) produced by Hjelmco Oil, Sweden. The both AVGAS types are produced according to the current standard specification for Aviation Gasolines, ASTM D910.

The piston engine tests are done at the airport DLR, Oberpfaffenhofen.
A TSI Scanning Mobility Particle Sizer system (SMPS) with long DMA was used to do the particle measurements. Test points are the ICAO power settings Taxi, Approach, Climb and Take Off and Cruise. The piston engine tests are done at the airport DLR, Oberpfaffenhofen. Additional EDX (Energy Dispersive X-ray) tests of filter samples are done in order to identify the composition of the particles.

The measurements show that the particle mean diameter and number concentrations for the piston engines are similar to the emissions known from jet engines and diesel cars! The comparison of leaded and unleaded AVGAS show a significant reduction in particle diameter and number concentration for the AVGAS 91/96 UL.

Conclusion:

- AVGAS powered flight piston engines emit nanoparticles
- AVGAS 100LL combustion emit high amount of soot- and lead bromide nanoparticles
- unleaded AVGAS 91/96UL, produced by **Hjelmco Oil (Sweden),** gives **significant lower emissions** in particle number concentration, in particle mass and in particle diameter
- AVGAS 91/96UL combustion emit a **significant lower particle surface area** per volume

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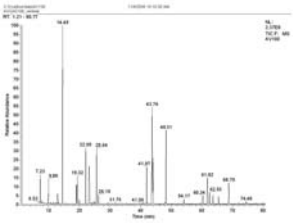
Why these tests?

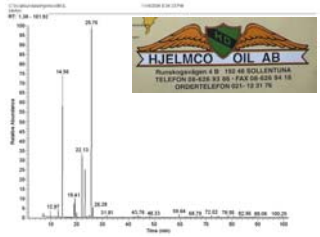
- small aircraft piston engines often have to run under fuel rich conditions, in order to keep the engine temperatures low

- fuel rich combustion can produce soot nanoparticles!

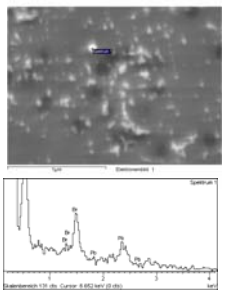
AVGAS 100LL 560 mg lead / liter



AVGAS 91/96UL unleaded



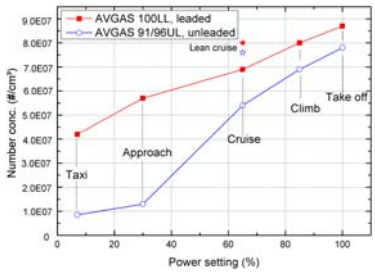
EDX- Spectra AVGAS100LL



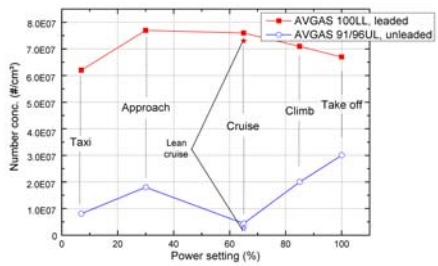
HB-EYS- ROBIN DR400
-Federal Office of Civil Aviation, Bern, Switzerland
-Lycoming O-360 180 HP
-Carburettor

SE_KEI- Piper 28 Warrior II
-Hjelmco Oil, Sweden
-Lycoming O-320 D3G 160HP
-Carburettor

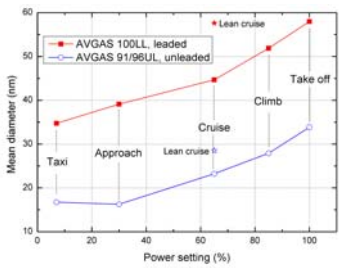
HB-EYS Number Conc. vs. Power Setting



SE-KEI Number Conc. vs. Power Setting



HB-EYS Mean Diameter vs. Power Setting



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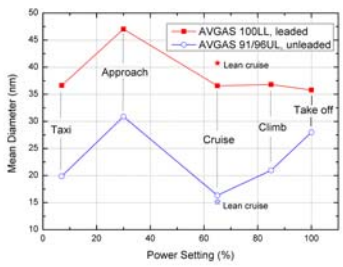
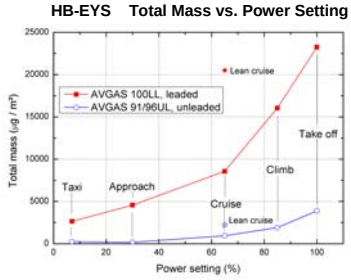
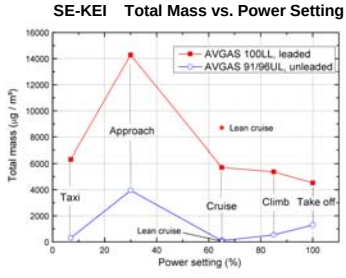


HB-EYS Total Mass vs. Power Setting



SE-KEI Total Mass vs. Power Setting



Conclusion

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-AVGAS 100LL combustion emit high amount of soot- and lead bromide nanoparticles

-unleaded AVGAS 91/96UL ,produced by Hjelmco Oil (Sweden), gives **significant lower emissions** in particle number conc.#, in particle mass and in particle diameter

-AVGAS 91/96UL combustion emit a **significant lower particle surface area** per volume

-The engine manufacturer Textron Lycoming has included AVGAS91/96UL as an approved alternate aviation gasoline for a large number of their engines already in year 1995. The engines with type numbers are listed in their service instruction No. SI 1070

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