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Nanoparticles in the Exhaust Gas of all IC-Engines?
NANOPARTICLES
in the Exhaust Gas of all kind
IC-Engines?

by

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➢ Ambient conditions and dilution air
➢ Gasoline and Diesel cars
➢ Continuously Regeneration Trap
➢ Small 4-stroke gasoline engines
➢ Summary
➢ Acknowledgement

In the present paper some examples of results of the past year are represented.

Ambient air
The numbers of particles in the ambient air usually vary between 100 and 1000 per ccm, Fig. 1.
In the dilution tunnel of an CVS-installation the level of particle numbers (PN) is lower, because of the dilution air filter. A modern gasoline car produces a similar level of PN-emission as the values in the dilution tunnel, Fig. 2.
Other sources and particularly the smokers contribute also to the PN-emission. Fig. 3 compare it with the Liebherr construction machine DI-Diesel engine.

Gasoline and Diesel cars
Fig. 4 shows the comparison of the particles size spectra of a modern automotive DI-TC-diesel engine and a modern gasoline engine. The maximum for the diesel engine is by the diameter of 100 nm and its value exceeds even the usual value of 1 million particles per cm². The particulate counts of the gasoline engine are about three ranges of magnitude lower, than those of the diesel engine.

For the diesel engines it can be concluded, that due to the heterogeneous combustion the modern developments of the engine technology are unable to substantially suppress the formation and emission of nanoparticulates.

Additives can be used in the passenger cars as antiknock agents for gasoline-, or for the additiv supported particle trap regeneration for the Diesel engines. As the Fig. 5 and Fig. 6 show on the example of ferrocen – the usually necessary concentrations don’t have any influence on the nanoparticles.
CRT—Continuously Regeneration Trap
Particulate traps are very efficient exhaust gas aftertreatment systems to cut down the particles mass- and count emissions. During the last ETH-Nanoparticle Workshop the author reported about the experiences of the VERT-Building Machinery Field Test with very good results with particulate traps after in average 2375 hours of operation.

CRT is an innovative system, which utilizes an oxidation catalyst before the trap. Some results with CRT on the Liebherr engine are given in the Figures 7 and 8.

The results can be summarized as follows:
- the CRT has a very good filtration efficiency in all operating points and at transient conditions (free acceleration),
- the counts of nanoparticulates are reduced with CRT very efficiently to, or below the level of ambient air quality,
- the CRT- system acts also as an oxidation catalyst and reduces strongly CO and HC,
- there are no problems with increase of the back pressure- the continuous regeneration takes place.

A very low sulfur fuel is necessary, what can cause any problems today, but it shouldn’t be a problem in view of the future perspective of the diesel sulfur content.

Small 4-stroke gasoline engines
There is a need of emission reduction of small machines for agriculture, or gardinery.

A simple and low cost post-equipment system of HJS using a bypass valve to control the rich operated carburetor to Lambda = 1, reduces engine out emissions and reduces fuel consumption even with simple carburetors.

At Lambda = 1 the 3-way catalyst is able to reduce CO, HC and NOx with a high efficiency.

Another measure of improvement is a special sulfur- and aromats- free fuel Aspen.

Both of these possibilities were investigated on two Briggs & Stratton engines with the measurement of nanoparticles with SMPS.

Fig. 9 shows the integrated particles numbers for both engines at different operating points.

The 2-cylinder-engine represents a newer generation with lower basic emissions values. The 3-way-catalyst has on this engine a reduction potential also for the nanoparticulates.

Fig. 10 gives an example of size distributions: there is no big difference for different fuels, but a clear and repetitive influence of the hydrocarbon trap (thermocenuder).

The emissions of nanoparticulates of those engines consist by a higher amount of the VOC. These emissions depend of air excess factor λ and of the basic HC-level.

The investigated special fuel has no influence on the nanoparticles.

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Summary

- Nanoparticles concentration in the ambient air is in the range of magnitude 10^-3.

- Gasoline engines with recent technology have the nanoparticles emission in the range of ambient air.

- Gasoline engine
  - at rich operation (full load)
  - with older technology (higher oil consumption, higher HC-level)
    have a considerably higher nanoparticles emission level

- Particulate traps and CRT are very efficient to eliminate the nanoparticles

- The metal additives don't increase the nanoparticles, if used with catalyst, or trap.

Title: always ? → yes !
but we can do a lot against it !
Fig. 1
particulate counts in the ambient air
during the measurements on engine dynamometer

with thermodenuder, engine: Liebherr D914T

Fig. 2
Particles size spectra in the CVS-dilution tunnel
with and without exhaust gas

Vehicle 1: 3-Way-Catalyst, 1780 cm³, nonleaded gasoline

- exhaust gas in dilution tunnel
- air in dilution tunnel engine off

50 km/h

90 km/h
Fig. 3

Diesel Emissions with and without Particle Trap vs. Ambient Air Particle Concentrations

number concentration $dN/d\ln D_p$ [cm$^{-3}$]

1400 rpm/50% load without trap
smoker room ambient air
2 cig. smoked in 50 m³
1400 rpm/50% load downstream of the trap
clean room ambient air

mobility diameter [nm]

Fig. 4

Comparison of modern automotive engines: diesel vs. gasoline

DI Diesel, 1900ccm, 2000rpm, 10.5kW
4V Gasoline, 1800ccm, 2800rpm, 10.5kW
CRT-Filter, Greenenergy fuel engine: Liebherr D914T at 1400min⁻¹, full load with thermodenuder

1.10E-6  1.10E-5  1.10E-4  1.10E-3  1.10E-2  1.10E-1  1
concentration [cm⁻³]
diameter [nm]

1.10E-6  1.10E-5  1.10E-4  1.10E-3  1.10E-2  1.10E-1  1
concentration [cm⁻³]
diameter [nm]

corr

1.10E-6  1.10E-5  1.10E-4  1.10E-3  1.10E-2  1.10E-1  1
concentration [cm⁻³]
diameter [nm]

1.10E-6  1.10E-5  1.10E-4  1.10E-3  1.10E-2  1.10E-1  1
concentration [cm⁻³]
diameter [nm]

corr
Integrated numbers of particles in the size spectrum 20-200nm with CRT-filter, engine: Liebherr D914T
Integrated numbers of particles in the size spectrum 20-500 nm
with thermodenuder

Fig. 9

Engine: Briggs & Stratton 2YR (2 cylinder)

Engine: Briggs & Stratton 11HP (1 cylinder)