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Analysis of Exhaust PM Composition Emitted from Non-Sooting Volatile Alcohols

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Introduction

The combustion engine, a well-known source of aerosols, has seen remarkable improvements regarding efficiency and emissions. A drawback of the conventional compression ignition (CI) engine is its requirement for a high cetane number fuel, i.e. diesel which contains long carbon chains forming particulate matter (PM) when combusted in the conventional diesel combustion (CDC) process.

A previous study of PM from partially premixed combustion (PPC) and CDC utilizing ethanol and methanol in a Scania D13 engine without emission after treatment systems (EATS) showed that the particle sizes from the alcohol combustion never exceeded 30 nm in diameter. Until now, the characteristics (origin, formation and constituents) of these nano-sized particles formed in the PPC and CDC process were unknown. It has been hypothesized that they originate from lubrication oil and engine wear.

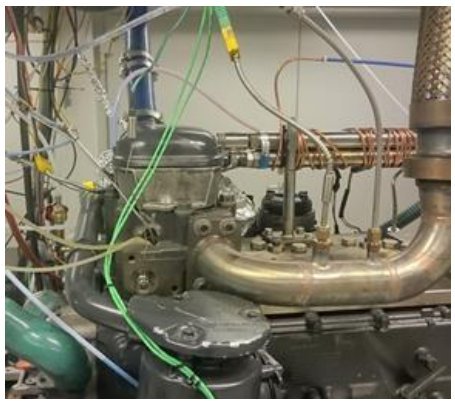
Method

Displaced volume [cm³]	2124
Stroke [mm]	160
Bore [mm]	130
Con. rod length [mm]	255
Compression ratio [-]	17.3:1
Number of valves [-]	4
Swirl ratio [-]	2.1
Exhaust valve open [-]	137° CAD ATDC
Inlet valve open [-]	-141° CAD ATDC

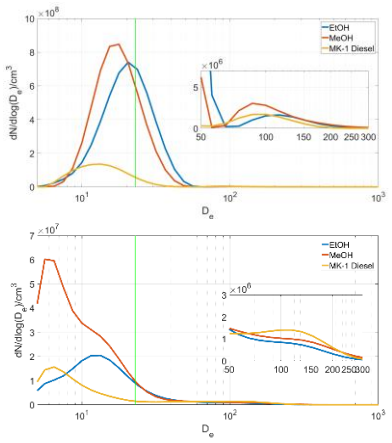
Tested Fuels
- MeOH
- EtOH
- Diesel

Operation Conditions
- 6 bar, 10 bar $IMEP_G$
- 1200 rpm
- CA50 at 5 CAD ATDC
- $\lambda \approx 3.0, \lambda \approx 1.9$
- 21% intake O_2 conc.

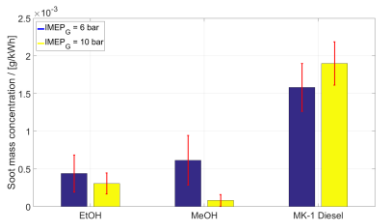
Measurements
- Measurements of gaseous exhaust (AVL AMA i60)
- Soot mass concentration (AVL MSS)
- Particle size distribution (Cambustion DMS500)
- Transmission electron microscopy (JEOL JEM 3000F)



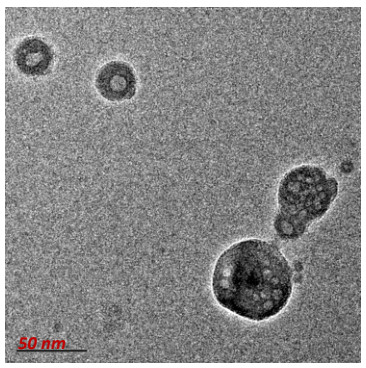
Results and Conclusions



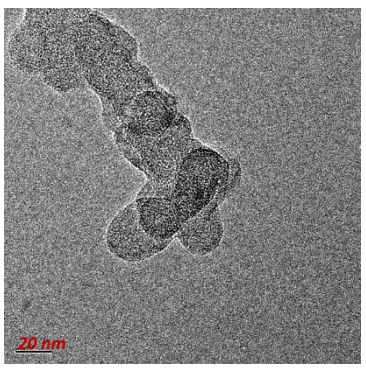
Particle size distribution
- Particle amount is consistently highest for MeOH, followed by EtOH and finally Diesel.
- At higher loads, the accumulation mode can be seen to increase for Diesel, in comparison to the alcohols while the nucleation mode particles decrease for all three fuels.



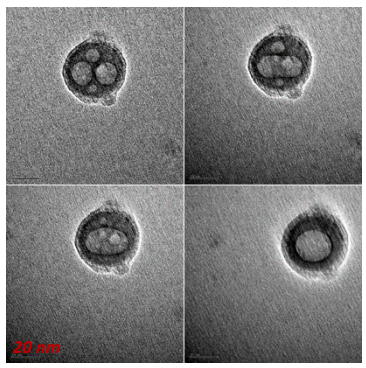
Soot mass concentration
- Soot higher for Diesel than MeOH and EtOH.
- Soot mass for alcohols higher at higher loads.



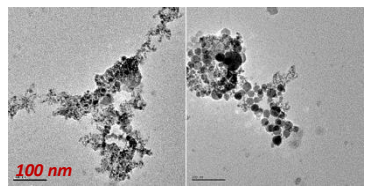
TEM analysis for alcohols
Particles from alcohol combustion consisted of nanoparticles in the size range between 5-50 nm as well as larger more complex agglomerates.



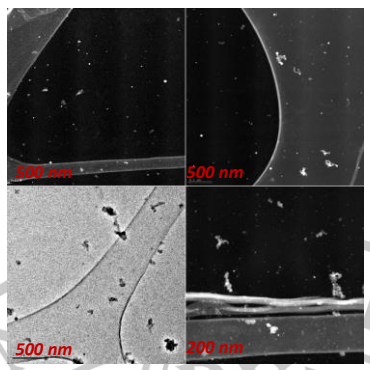
Although less common, the larger and more complex soot agglomerates could be found on the alcohol exhaust grid.



- The nucleation mode particles where spherical with one or more holes in the center of the particle.
- The cavities located in the center of the particles were not stable under the influence of the electron beam as they were merging into bigger holes.
- Not clear if the hole is in fact a hole or a liquid phase.
- The main elemental constituents of the EDX analyzed particles were Zn, Ca, P, S, believed to originate from the engine lubricant.



TEM analysis for Diesel
Agglomerates of metallic nanoparticles were found on the diesel TEM grid.



Diesel-alcohol exhaust PM comparison
Alcohol exhaust contains larger amounts of nano sized PM (upper photos) while PM emitted from diesel combustion has a significantly higher amount of larger agglomerates (lower photos).

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