Number Measurements and Size Dependent Volatility of Diesel Exhaust Particles

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SUMMARY

An in-house developed volatility tandem differential mobility analyzer (v-TDMA) instrument in tandem mode has been used to study the exhaust particles of a heavy-duty Diesel engine equipped with a continuously regenerating trap (CRT) at two steady state conditions: medium speed / 100 % load and high speed idle. By use of the tandem mode of the v-TDMA instrument, particles in a narrow size range are led to the heater and the size dependent volatility can be studied. The sample was extracted directly from the exhaust system and conditioned by use of a rotating disc diluter. Temperatures between ambient temperature and 350 °C have been applied to the heated section inside the v-TDMA instrument to study the volatility of the particles. A second line with a stand-alone CPC preceded by a heater gives the total number concentration of particles. The current work indicates that particles generated by the engine equipped with CRT at high load do not separate in smaller sizes when heated. The particles remaining after heating have the same size as before being heated. At high speed idle, small fractions of material can be found as smaller sized particles after heating.

When applied on exhaust sampled down-stream a CRT, the measurements shows variations in both total particle number concentrations and size separated number concentrations also after stabilizing the engine for over 20 minutes. The varying concentrations occur also after applying heat to the aerosol or the specific particle size. Such variations need to be avoided when number concentration measurements shall be used for the future emission standard. To perform number concentration measurements with comparable results, it has shown important to state all conditions of the measurements very carefully and to condition not only the engine but also the aftertreatment device. This will be a major challenge for future number based measurement procedures for type approval of engines.

The current study was an attempt to study the size separated volatility of exhaust particles by use of an in-house developed research instrument. In summary, the work point out the difficulties of particle number measurements including varying concentrations and transformation of particle size. The v-TDMA instrument, although reliable for ambient air measurement, has shown troublesome to apply on an engine. The main reasons are the requirements from the instrument's software on stable, lognormal size distribution data and the sensibility of the instrument for varying inlet concentrations. During the present study, particle reduction in the v-TDMA instrument was strongly associated with losses due to transfer function discrepancies and thermophoresis, which could not easily be corrected for during the measurements. The influences of dilution and varied temperature could therefore not be thoroughly evaluated.

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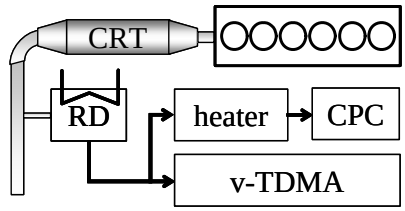
Motivation

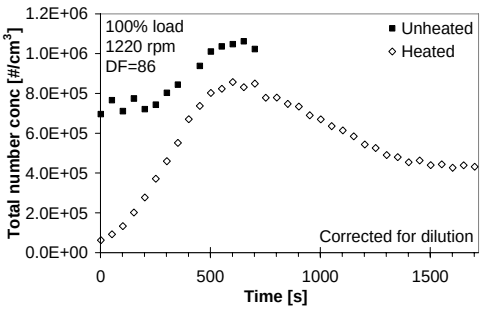
New particle measurement methods for type approval of engines have been developed. The Euro 5/6 emission legislation includes measurement of the total particle number in a thermally conditioned exhaust aerosol. Hot rapid dilution is applied to quench nucleation and condensation. When a new standard is approved, it is essential to know how the proposed measurement procedure, including sampling and dilution, influences the aerosol.

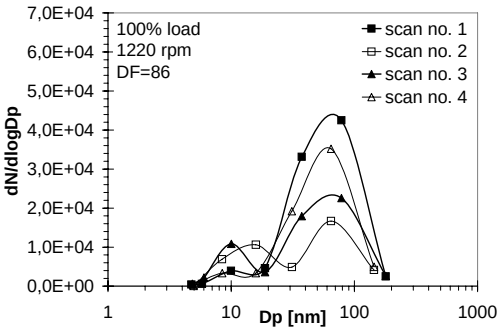
The aim of the current project is therefore to enable characterization of the engine exhaust aerosol so that an understanding of the aerosol properties and the behaviour of exhaust particles under different conditions can be reached.

Experimental set-up



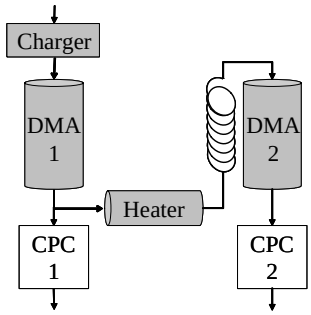
Varying concentration



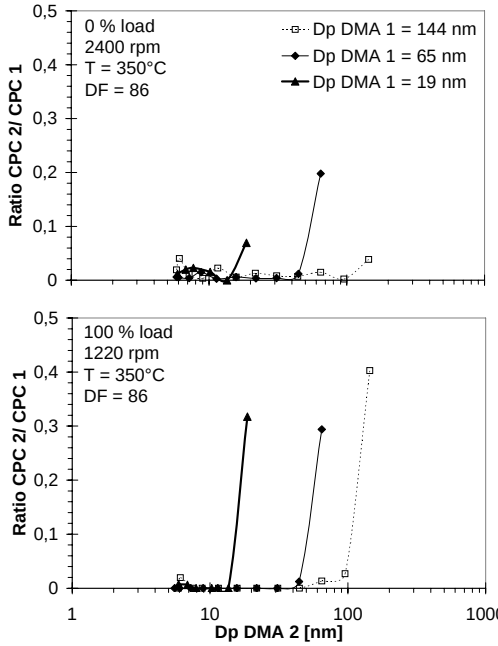


Down-stream a CRT, variations in both total particle number concentration and number size distribution can be seen also after stabilizing the engine for 20 minutes. Concentration instabilities occur also after thermal conditioning of the sample.

v-TDMA instrument



The diagram shows v-TDMA results after heating the aerosol to 350°C. Test have been performed at idle and high load. Size distributions for particles with a selected original diameter of 19 nm, 65 nm and 144 nm are shown.



Particles generated by the engine equipped with CRT at high load have the same size after being heated to 350ºC as before. At high speed idle, small fractions of material can be found as smaller sized particles after heating. The consistently lower ratios at idle compared with full load indicate that the particles holds greater amount of volatile material at idle than full load.

Conclusions

The work was an attempt to study the size separated volatility of exhaust particles by use of an in-house developed research instrument. The study highlights the difficulties of particle number measurements including varying concentrations and transformation of particle size. The v-TDMA instrument, although reliable for ambient air measurement, has shown troublesome to apply on an engine with exhaust aftertreatment. The main reason is the requirement for stable, lognormal size distribution data. Without conditioning of the aftertreatment device, variations also in the total particle number concentration was experienced. Preparation of the aftertreatment devices may become a major challenge during future number based measurement procedures for engine certification.

EMIR-1 Sampling and measurement of engine exhaust particles

The study is done as part of the Swedish national research cooperation program EMIR-1 (EMIssion Research) between the Swedish state and the automotive industry including the companies AVL MTC, Saab Automobile / GM Powertrain, Scania CV, Volvo Car Corporation, Volvo Technology Corporation and Volvo Powertrain.

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