

Cachón L., Imhof D. / Matter Aerosol AG, Switzerland

NanoMet3: Portable Solid Nanoparticle Counter for Vehicle Exhaust Emissions

Introduction

Portable Emission Measurement Systems (PEMS) have been proven for certain applications to better identify in-use performance of vehicles than standard laboratory measurements. They are designed to measure emissions during the actual use of an internal combustion engine vehicle or equipment in its regular daily operation under real-world conditions. Furthermore PEMS constitute a cost effective solution to perform in-service testing of heavy-duty engines: rather than extracting the engines from the vehicles and then installing them on an engine dynamometer to run their official regulatory cycles, the vehicles are equipped with on-board emission measurement systems and tested during their real in-use operation.

The PEMS methodology has been recognized by many governmental entities such as the USEPA and the United Nations Framework Convention on Climate Change or UNFCCC. Particle counting on diesel car is mandatory through Euro 5B since September 2011 and described according to Particle Measurement Program–PMP. The European Union and other countries throughout the world will continue to integrate particle counting into their emission standards, especially since the WHO identified the soot nanoparticles being one the most dangerous pollutant. Moreover, these days the European Commission is working on the approach for the technical assessment of Portable Emission Measurement Systems–PEMS for particle concentration emitted by light duty vehicles. The oncoming test procedure may include on-road measurements as an extension of the PMP program.

Matter Aerosol's NanoMet3 portable solid particle counter is a general-purpose counter that detects airborne particles down to 10 nm. It provides highly accurate measurements over a wide concentration range. As a result, this portable solid particle counter is quite versatile and well-suited for a broad range of applications.

Measurement method

Thermo-Dilution

NanoMet3 separates sampling and conditioning of the aerosol. Conditioning of the raw gas is carried out according to PMP requirements:

1. Unique dilution of combustion engine emissions from tail pipe or CVS with a Rotating Disk Diluter. The dilution in an adjustable factor range from 10 to 300 takes place in a rotating disk-block whose construction minimizes thermophoretic losses.
2. Removal of volatile particles in the Evaporation Tube where the temperature can be adjusted up to 350°C. No recondensation takes place in the cooling down zone assuming the measuring gas is below the dew point after dilution [1].

Particle Measuring Principle

NanoMet3 is equipped with a Diffusion Size Classifier - DiSC sensor [2] which charges the aerosol in a unipolar diffusion charger. The charged aerosol passes through a diffusion stage where particles are deposited by diffusion and detected as an electrical current. The remaining particles end up in a second stage, the filter stage, and also the current is measured. The ratio of the two currents is a

measure of the average particle size and is determined during the instrument calibration. Because the charge per particle is a function of particle diameter once this is known, the particle number can be computed from the total current and flow rate.

Experimental results

Several campaigns on the chassis dynamometer with different vehicle engine technologies and EURO V emission standards have been carried out to assess the measuring method. The experiments show the measuring performance of NanoMet3 compared with PMP-Benchmark system during NEDC transient driving. Time response of the NanoMet3 is fast enough to follow transient cycles. Due to different exhaust sampling point for NanoMet3, fitted on the vehicle exhaust tailpipe, and PMP-System, sampling at CVS, higher peak concentrations of nanoparticles corresponding to raw emissions are visible from NanoMet3. However, the measurements have demonstrated a good correlation of particle number between NanoMet3 and PMP-system.

Conclusions

As a portable solid nanoparticle counter, NanoMet3 constitutes a new instrument to measure number concentration and average diameter of nanometer sized particles in the size range 10 – 700 nm. It is compact, easily portable, rugged design and provides on-line response. Due to these properties it is a useful instrument for number concentration measurements in non-laboratory settings and even OBD instrumentation. The particle number concentrations measured with NanoMet3 agree well with those measured with a condensation particle counter on chassis dynamometer. NanoMet3 is therefore a candidate for in-use-compliance testing as well as for future PEMS type approval.

References

- [1] Kasper, M., “The Number Concentration of Non-Volatile Particles -Design Study for an Instrument According to the PMP Recommendations” SAE 2004-01-0960
- [2] Fierz, M., Burtscher, H., Steigmeier, P., Kasper, M., “Field measurement of particle size and number concentration with the Diffusion Size Classifier (DiSC)” SAE 2008-01-1179, DOI: 10.4271/2008-01-1179

Acknowledgements

We would like to thank all the automobile manufacturers, researchers and technicians for their valued support during the tests within the development of NanoMet3.

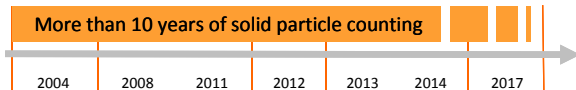
NanoMet3: Portable Solid Nanoparticle Counter for Vehicle Exhaust Emissions

Luis Cachón, David Imhof
Matter Aerosol AG



INTRODUCTION and MOTIVATION

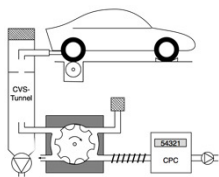
These days the European Commission is working on the approach for the technical assessment of Portable Emission Measurement Systems – PEMS for particle concentration emitted by light duty vehicles. The oncoming test procedure may include on-road measurements as an extension of the PMP program.



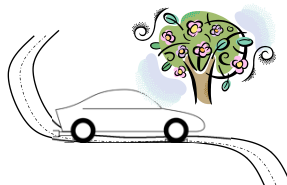
- 2004 Matter delivers the Golden Instrument for the PMP tests
- 2008 Particle counting is decided for Euro5b/6
- 2011 Euro 5b
- 2012 WHO identified soot nanoparticles as most dangerous pollutant
- 2013 Solid particle count introduced in Europe for heavy duty
- 2014 Euro 6
- 2017 European Commission PEMS-PN

PEMS have been proven for certain applications to better identify in-use performance of vehicles than standard laboratory measurements. They are designed to measure emissions during the actual use of the vehicle or equipment in its regular daily operation under real-world conditions. Furthermore PEMS constitute a cost effective solution to perform in-service testing of heavy-duty engines.

PMP sampling and conditioning



On-road measurements



Matter Aerosol's PEMS: NanoMet3

=



Figure 1: NanoMet3, PEMS-Particle Number instrumentation for oncoming legislation

MEASUREMENT METHOD

Thermo-Dilution

NanoMet3 separates sampling and conditioning of the aerosol. Conditioning of the raw gas is carried out according to PMP requirements:

- 1. Unique dilution of combustion engine emissions from tail pipe or CVS with a Rotating Disk Diluter. The dilution takes place in a rotating disk-block minimizing thermophoretic losses.
- 2. Removal of volatile particles in the Evaporation Tube. No recondensation takes place in the cooling down zone [1].

Particle Measuring Principle

NanoMet3 is equipped with a Diffusion Size Classifier - DiSC sensor [2].

- Particles are labeled with positive charges in a unipolar charger.
- Particles are deposited by diffusion and detected as an electrical current.
- Remaining particles end up in a second stage, the filter stage, and also the current is measured.
- The ratio of the two currents is a measure of the average particle size and is determined during the instrument calibration.
- Because the charge per particle is a function of particle diameter once this is known, the particle number can be computed from the total current and flow rate.

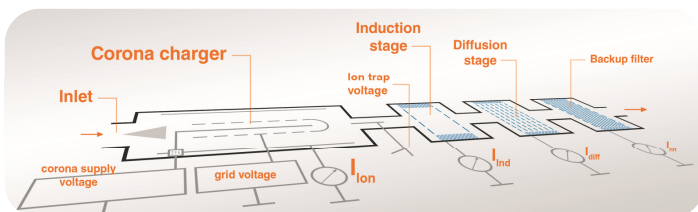


Figure 2: Setup of the particle sensor DiSC

EXPERIMENTAL RESULTS

The left graphic of next figure shows the measuring performance during a NEDC transient driving cycle of NanoMet3 compared with PMP-Benchmark system. Time response of the NanoMet3 is fast enough to follow transient cycles.

Right graphic shows the correlation of particle number between NanoMet3 and PMP system. Two test vehicles with gasoline direct injection and compression ignition engine and EURO V standards were driven at chassis dynamometer. The exhaust sampling point for NanoMet3 was fitted on the vehicle exhaust tailpipe while PMP-System sampling took place at CVS.

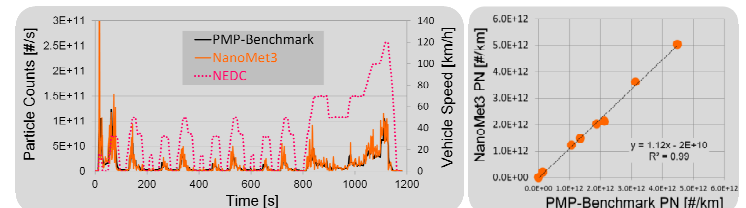


Figure 3: Number concentration and correlation measured with NanoMet3 and PMP-Benchmark during a New European Driving Cycle

CONCLUSIONS

As a portable solid nanoparticle counter, NanoMet3 constitutes a new instrument to measure number concentration and average diameter of nanometer sized particles in the size range 10 - 700 nm. It is compact, easily portable, rugged design and provides on-line response. Due to these properties it is a useful instrument for number concentration measurements in non-laboratory settings and even OBD instrumentation. The particle number concentrations measured with NanoMet3 agree well with those measured with a condensation particle counter on chassis dynamometer (correlation coefficient $R^2 = 0.99$). NanoMet3 is therefore a candidate for in-use-compliance testing as well as for future PEMS type approval.

REFERENCES

- [1] Kasper, M., "The Number Concentration of Non-Volatile Particles -Design Study for an Instrument According to the PMP Recommendations" SAE 2004-01-0960
- [2] Fierz, M., Burtcher, H., Steigmeier, P., Kasper, M., "Field measurement of particle size and number concentration with the Diffusion Size Classifier (DiSC)" SAE 2008-01-1179, DOI: 10.4271/2008-01-1179

ACKNOWLEDGEMENTS

We would like to thank all the automobile manufacturers, researchers and technicians for their valued support during the tests within the development of NanoMet3.

SPECIFICATIONS

NanoMet3 portable solid particle counter provides a complete data string with following values:

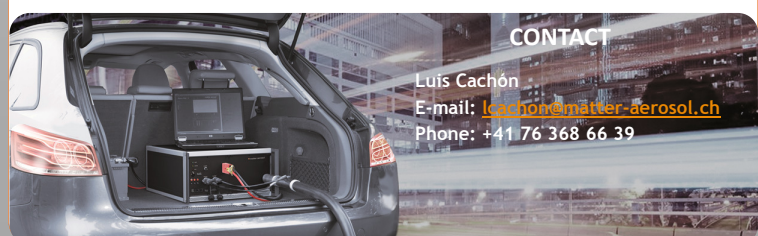
- particle number concentration ($\#/\text{cm}^3$)
- average size (nm)
- calculated particle mass (mg/m^3)
- LDSA – Lung Deposition Surface Area ($\mu\text{m}^2/\text{cm}^3$)

The communication is carried out via:

- AO, RS232, AK protocol
- USB, Secure Digital Memory Card, LAN/Ethernet port, and optional WLAN

Following are some of the specifications:

- raw gas particle concentration range: $1\text{E}3 \dots 3\text{E}8 \text{pt}/\text{ccm}$
- particle size: 10...700 nm (within mode diameter of 10...300 nm)
- dilution factor: 10, 100, 300 (optional customized dilution factor)
- power supply: 12VDC - 24 VDC / 100 VAC - 240 VAC
- power consumption: 300 W under standard ambient conditions
- weight: approx. 18 kg; with complete connections: ca. 23 kg
- calibration: standard calibration with NaCl particles, 90 nm



CONTACT

Luis Cachón
E-mail: lcachon@matter-aerosol.ch
Phone: +41 76 368 66 39