Portable Nano-Particle Emission Measurement System

EUROPEAN COMMISSION
Horizon 2020 | GV-02-2016 | Technologies for low emission light duty powertrains
GA # 724145

Deliverable No.	D3.3	
Deliverable Title	PN measuring system: requirements & application	
Deliverable Date	2018-05-31	
Deliverable Type	REPORT	
Dissemination level	Confidential – member only (CO)	
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Status	Final	2018-08-11

Publishable Executive Summary

The PEMs4Nano project addresses the challenge to develop detectors and robust procedures to reliably measure the particle number concentration down to 10 nm in the exhaust gas. To achieve this and to make the progress to that overall objective more transparent the project is structured in three focus areas:

- model-guided application (MGA),
- preparation of measurement technology (MT),
- development of measurement procedure and application (MPA).

The simulative approach in *model-guided application* supports building up fundamental understanding of the particle formation, composition, size distribution and transport and generates vital recommendations on the measurement procedure. *Preparation of measurement technology* focuses on the development of the PN measurement system itself while *development of measurement procedure and application* addresses the implementation of the new measurement system in the engine & vehicle development process in terms of application and usage.

This report gives an overview of the investigations on the multi-cylinder engine test bench that have the following three objectives:

- Generate experimental data to train and validate the models of the focus area *model-guided application.*
- Evaluate if the new PEMs4Nano lab measurement systems meets the requirements in terms of response time and capability to remove volatiles. For that, the corresponding behavior of an established PN23 measurement system is used as a reference.
- Derive an understanding on the application of the new PEMs4Nano lab measurement system and evaluate how far the experience gathered with the established PN23 measurement systems over the last years can be transferred to the new measurement system.

For the investigations, a state-of–the-art gasoline direct injection prototype engine is operated on an engine test bench. The engine is equipped with a 35 MPa injection system and for the exhaust gas aftertreatment a three-way catalyst and a gasoline particulate filter are applied. Comprehensive variations of PN sampling positions & engine operating conditions (load, speed, temperature, fuel type) are performed. Even the speed & load profile of an RDE-like driving cycle is applied to the engine on the engine test bench to get as close to "real driving conditions" as possible.

In terms of requirements the PEMs4Nano lab measurement system and the establish PN23 measurement system show a similar response time both on the lower detection threshold and on / close to the upper detection threshold. Furthermore, both measurement systems are able to remove even high concentrations (10^7 – 10^8 #/cm³) of volatiles in the sampled exhaust gas. Only at low load the PEMs4Nano lab measurement system seems to let some volatiles slip through the catalytic stripper. This finding will be further analyzed and the configuration of e.g. the catalytic stripper will be modified if needed.

The investigations especially with the gasoline particulate filter show that depending on the sampling position (upstream or downstream of the gasoline particle filter, GPF) the PN concentration in the exhaust gas can be on very different levels, which raises the need for PN measurement systems that are capable to precisely measure a wide range of PN concentrations from $10^2/10^3$ up to 10^8 particles/cm³ (or even higher).

In terms of application of the PEMs4Nano lab measurement system the comprehensive engine investigations show that if the sampling position is upstream of the GPF the new measurement system can be applied and operated like an established PN23 measurement system. Of course, the PN10 emission is higher than the PN23 emission, but we do not observe that this “offset” has a clear dependency on the engine operating condition. The experience that the fuel type has a high impact on the PN23 emissions applies to the PN10 emissions as well.

If the sampling happens downstream of the GPF the overall PN concentration (PN10 and PN23) highly depends on the filtration efficiency of the GPF which itself depends on the load condition of the filter and the size of the particles that enter the filter. Therefore, filtration efficiency is neither constant for every particle (size dependency) nor constant over the engine operating time (changing load condition). Accordingly, it is more difficult to correlate PN10 and PN23 emissions to specific engine operation maneuvers or changes of the engine calibration, if the PN sampling position is downstream a GPF. Thus, when it comes to the calibration of an engine a PN sampling position upstream of the GPF is recommended. However, when the focus of an investigation is to evaluate the PN exhaust emissions in terms of “How much particles are emitted in the environment?” it is mandatory to sample at the tailpipe. For the evaluation of the PN measurement it is important to keep in mind that the emitted PN does not just depend on the engine operating conditions, but on the condition of the GPF as well.

The gathered findings summarized in this report will be used to further improve the measurement technology on the one hand and to contribute to a recommendation for a PN >10 nm measurement procedure for the application in the engine development process on the other hand.

Acknowledgement

The author would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:

#	Type	Partner	Partner Full Name
1	IND	HORIBA	Horiba Europe GmbH
2	IND	Bosch	Robert Bosch GmbH
3	IND/SME	CMCL	Computational Modelling Cambridge Limited
4	IND	TSI	TSI GmbH
5	HE	UCAM	The Chancellor, Masters and scholars of the University of Cambridge
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7	IND	IDIADA	Idiada Automotive Technologie SA
8	IND	HORJY	Horiba Jobin Yvon S.A.S.
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This project has received funding from the European Union's Horizon2020 research and innovation programme under Grant Agreement no. 724145.