WP3 – Measurement integration into system development

WP3 Aim & Objectives:
1. Particle characterization in exhaust line & validation of laboratory measurement technology
2. Development of a PN >10 nm measurement procedure for the application on a MCE test bench
3. Development of surrogate models for particle size distribution and composition
4. Assessment/improvements of instrumentation models associated with measurement technologies/procedures

WP3 Results & Outcome:
1. Report on characteristics (chemistry, size distribution & morphology) of particles down to 10 nm
2. Recommendation for a reliable & robust PN > 10 nm measurement procedure for the application in the engine development process
3. More robust instrumentation models associated with measurement technologies & procedures

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 724145
Experimental Setup

Single Cylinder Engine @ Bosch, Renningen

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Physico-chemical characterization of the smallest particles emitted by internal combustion engines

**Results & importance**

Extensive database on size-dependent particle structure, morphology, chemical composition ... for various working regimes of the single cylinder engine (engine setpoint) – used as particle generator

<table>
<thead>
<tr>
<th>Engine setpoint</th>
<th>RPM</th>
<th>pmi</th>
<th>Lambda</th>
<th>soi</th>
<th>fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2000</td>
<td>5</td>
<td>1.02</td>
<td>-270</td>
<td>Gasoline</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>10</td>
<td></td>
<td>-305</td>
<td>EURO5</td>
</tr>
<tr>
<td>Injection delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>10</td>
<td></td>
<td>-311</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PMI: in cylinder pressure (bar)
SOI: start of injection

**PEMS4Nano prototype optimization & Possible use in other projects for engine optimization**

Input for the complex model developed by CMCL & Univ. Cambridge

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Experimental Setup

On-line analysis by Laser-Induced Incandescence

\[ \text{Laser yag} @ 1064 \text{ nm} \ 10 \text{ Hz} \]

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Physico-chemical characterization of the smallest particles emitted by internal combustion engines

On-line analysis by Laser-Induced Incandescence

Variation of LII intensity: soot volume fraction

Variation of LII decay-time: « mean soot diameter » indicator

Increase of the soot volume fraction

Increase of mean soot diameter

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Experimental Setup

Size-selective sampling & off-line analyses by laser ionisation mass spectrometry, electron and atomic force microscopy, Raman spectroscopy

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Real time LII data can be compared to SMPS/EEPS/SPCS
Physico-chemical characterization of the smallest particles emitted by internal combustion engines

Size-selective sampling and off-line analyses
laser ionisation mass spectrometry + advanced statistical analysis

Determining the size related particle morphology from the Nano MOUDI samples
Physico-chemical characterization of the smallest particles emitted by internal combustion engines

Size-selective sampling and off-line analyses

Further analysis of particles by

- Electron microscopy (Scanning Electron Microscope / Transmission Electron Microscope)

- Atomic force microscopy

- Tip Enhanced Raman Spectroscopy (TERS)

Work In Progress . . . .
Model Guided Application (MGA)

- MGA combines physico-chemical and statistical algorithms to simulate the formation and evolution of the particulate emissions in IC engine driven vehicles.

MGA development offers:

- Sensitivity of PM and PN to operating conditions in IC engines and vehicles

- Particle size distribution, PM, PN, aggregate composition and morphology as a function of fuel characteristics, engine operating mode, after-treatment and RDE attributes

- Thermodynamic boundary conditions at various sampling points to reduce the need for measuring “everything”

- Improvement of the robustness of measurements procedure(s)
MGA interfaces with measurements

- MGA development:
  - Detailed particle population balance model within the SRM Engine Suite™ extended beyond soot to include ash, sulphates and volatiles
  - kinetics™ reactor network simulation to account for dilution and sampling

- Direct benefits to MGA from the Single Cylinder Engine measurements campaign:
  - Validation of engine-out particle size distributions at load-speed points

- Results, recommendations and next steps:
  - Dilution and temperature thresholds recommended by MGA based on the number density of solids and SOF
  - Size-resolved chemical characterisation of particles to be used to assess the MGA

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Workshop on particle measurement

The coordinators of the three particle measurement projects DownToTen, PEMs4Nano and SUREAL-23 are in the progress of organizing a two day event on the Measurement and Characterization of nanoparticles from powertrains.

**Proposed Date:** Tuesday, October 9th 2:00 PM – Wednesday, October 10th 2:00 PM

**Location:** Aristotle University 54124 Thessaloniki, Greece

It will cover presentations from different stakeholders with the following topics:

- Current EU/US/Japanese regulation trends,
- Results from the green vehicle projects (Upgrade, Dieper, Paregen, Eagle...)

... 

Please block the date – more information will be available shortly.
End of presentation

www.PEMs4Nano.eu