A QUANTITATIVE COMPARISON OF THE PARTICULATE MATTER EMISSIONS FROM TWO EURO 5 VEHICLES (DIRECT INJECTION PETROL & DIESEL)

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Concern over particulate matter emissions remains high, despite the roll-out of high filtration efficiency aftertreatment devices for CI (compression ignition, Diesel) engines, namely DPFs. Particle number limits are soon to be introduced for vehicles featuring spark ignition direct injection (SIDI) engines, but for the time being vehicles featuring such engines do not feature dedicated filters. There are various broad similarities between CI and SIDI engines, but the differences in the chemical properties of the fuel, the injection pressure, combustion temperature and presence or absence of a dedicated filter mean that the magnitude and character of solid exhaust emissions from the two engines types differ markedly. In this context, a quantitative comparison of emissions from modern vehicles featuring these engine types is an interesting and important research topic.

A series of experiments were performed on a chassis dynamometer in a climate-controlled test facility [1,2] to measure particulate mass (PM), particle number (PN) and size distribution, over the New European Driving Cycle (NEDC). PM and PN were measured according to the legislative procedure; particle size distributions were measured by passing a diluted exhaust gas sample through a particle sizer (TSI EEPS 3090). Two Euro 5 vehicles were tested: a CI vehicle (with an oxidation catalyst and DPF) and a SIDI vehicle (with a three-way catalyst but no dedicated filter). Both vehicles were passenger cars of similar engine displacement and unladen mass. Tests were performed at ambient temperatures of +25°C and -7°C (engine thermally conditioned and fully stabilized).

All three methodologies employed are were found to viable techniques for measuring particulate matter emissions from these vehicle types at both test temperatures and the absolute PN and PM emissions values obtained from the two vehicles over the NEDC at the two test temperatures were broadly as expected. For the CI vehicle, PM almost doubled and PN underwent an 85-fold increase; for the SIDI vehicle, PM suffered a 5-fold increase and PN almost doubled.

Comparing emissions from both vehicles at both temperatures, PM emissions from the SIDI vehicle were 1 to 2 orders of magnitude higher than emissions from the CI vehicle, while PN emissions were 3 to 4 orders of magnitude greater (Figures 1 & 2), no doubt largely due to the absence of a filter on the SIDI vehicle. The calculated PN/PM ratio varied between the two vehicles and with the ambient temperature, with distinct ratios and ratio temperature responses observed for the two engine types. The results were analyzed in order to compare the solid emissions characteristic of the two engine types. Despite the conceptual similarities between SIDI and Diesel engines, the properties of the particles they emit differ substantially, due to differences in particle formation mechanisms [3,4] and the absence of a SIDI filter (for the time being).

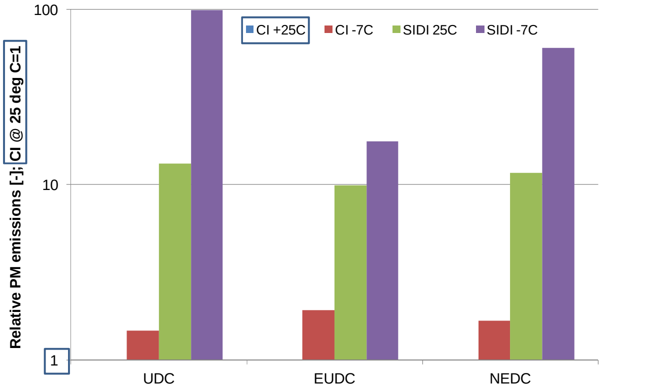

Figure 1. Relative PM emissions for both test vehicles at both test temperatures for the NEDC and its two phases

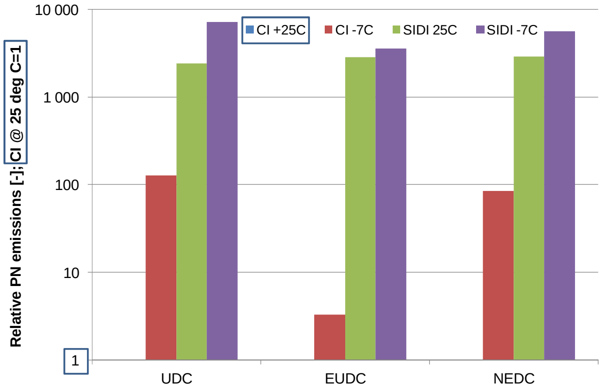

Figure 2. Relative PN emissions for both test vehicles at both test temperatures for the NEDC and its two phases

Ambient temperature was also found to change the emissions profile, with a noticeable shift in the modal particle diameter and the overall form of the distribution (Figures 3 & 4). SIDI particle abundances for *d*<20 nm appeared to be relatively weakly affected by the ambient temperature. Particle emissions from the CI vehicle at the higher test temperature were unexpectedly irregular, with a multi-modal distribution profile. Over the entire NEDC, an ambient temperature of -7°C caused a moderate shift towards greater particle diameters in a bell-curve distribution; at +25°C the distribution was altogether less heterogeneous (note the different scales on the vertical axes of Figure 3).

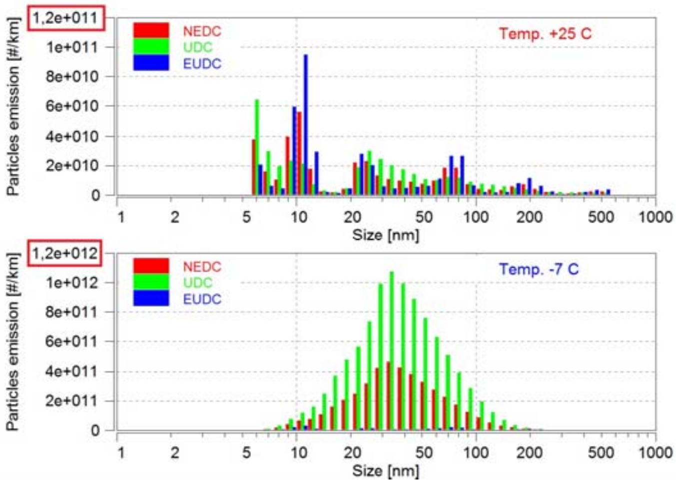

Figure 3. CI particle size distributions at both test temperatures for the NEDC and its two phases

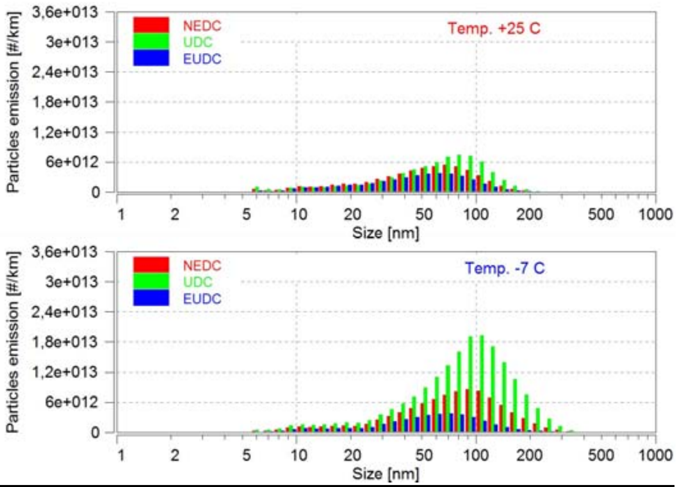

Figure 4. SIDI particle size distributions at both test temperatures for the NEDC and its two phases

Differences were found to be greatest during the UDC phase (due to cold start conditions: inhibited combustion, excess fuelling, limited oxidation of particulates in the DOC/TWC). Such a tendency concurs with the findings of various other studies and is noteworthy, since the UDC is broadly equivalent to a short urban journey performed from a cold start. Further work on these differences in the magnitude and characteristics of solid pollutants in vehicular exhaust gas and the resulting toxicological implications will inform political decisions regarding future automotive emissions legislation and test procedures. Research on SIDI emissions under real world conditions (including cold start, short journeys and low ambient temperature operation) is a research priority, given the dramatic increases seen lately for that engine type in the EU and in light of the upcoming particle number limits, which will eventually necessitate the fitting of a dedicated filtration device to SIDI vehicles.

References:

[1] Bielaczyc, P., Szczotka, A. and Woodburn, J., Development of vehicle exhaust emission testing methods – BOSMAL's new emission testing laboratory, Combustion Engines, ISSN: 0138-0346, 1/2011 (144), 3-12, 2011, bit.ly/19kvVl3.

[2] Bielaczyc, P., Pajdowski, P., Szczotka, A. and Woodburn, J., Development of automotive emissions testing equipment and test methods in response to legislative, technical and commercial requirements, Combustion Engines, ISSN: 0138-0346, 1/2013 (152), 28-41, 2013, bit.ly/11EcDCd.

[3] Feasibility of Introducing Particulate Filters on Gasoline Direct Injection Vehicles, JRC report 25297 EN, 2011. DOI:10.2788/23375.

[4] Eastwood, P., Particulate Emissions from Vehicles, (Chichester, England), 2008. ISBN: 978-0-470-72455-2.

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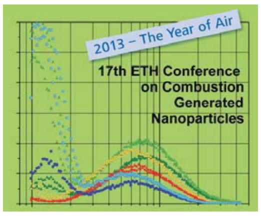

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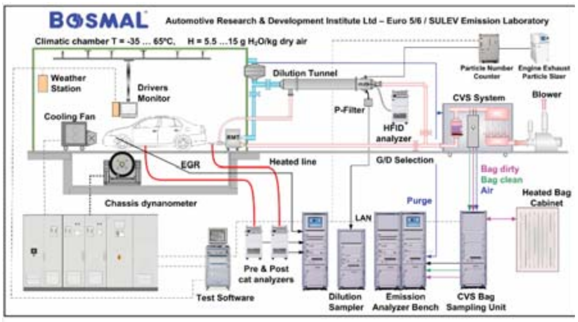
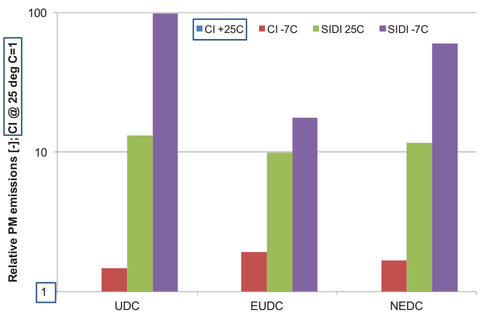
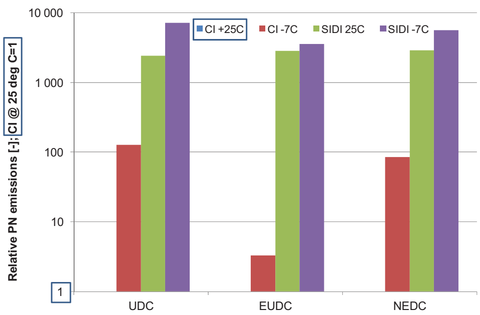


BOSMAL's Emission Testing Laboratory [1,2]

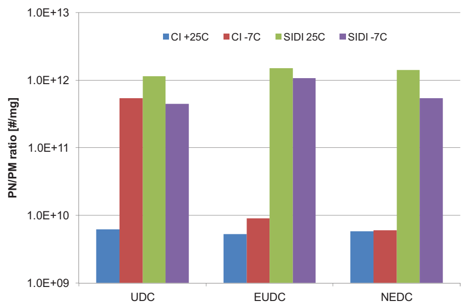
Equipment for quantification and characterization of particulate matter emissions – filter holder installation, particle counter, particle sizer



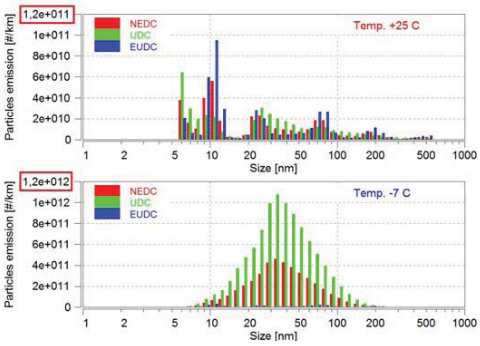
Relative PM emissions for both test vehicles at both test temperatures for the NEDC and its two phases



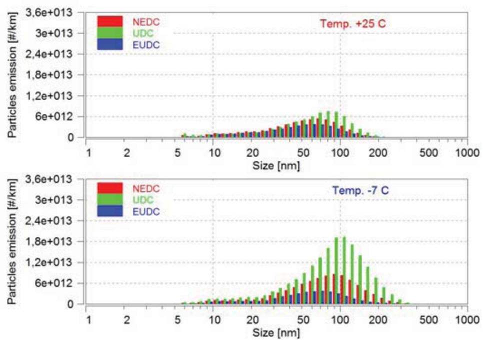
Relative PN emissions for both test vehicles at both test temperatures for the NEDC and its two phases



PN/PM ratio for both test vehicles at both test temperatures for the NEDC and its two phases



CI particle size distributions at both test temperatures for the NEDC and its two phases



SIDI particle size distributions at both test temperatures for the NEDC and its two phases

Overall observations:

- All three methodologies employed are viable techniques for measuring particulate matter emissions from these vehicle types at both test temperatures
- SIDI PM emissions are much higher than DPF filtered CI emissions; SIDI PN emissions are orders of magnitude higher
- Ambient temperature has noticeable impacts on particle mass, number, size distribution profile and modal diameter
- Differences are greatest during the UDC phase (cold start: inhibited combustion, excess fuelling, limited oxidation of particulates in DOC/TWC)
- Over the entire NEDC, a temperature of -7°C causes a moderate shift towards greater particle diameters in a bell-curve distribution; at +25°C the distribution is less heterogeneous
- SIDI particle abundances for *d*<20 nm appeared to be weakly affected by ambient temperature

References: [1] Bielaczyc, P., Szczotka, A. and Woodburn, J., Development of vehicle exhaust emission testing methods – BOSMAL's new emission testing laboratory, Combustion Engines, ISSN: 0138-0346, 1/2011 (144), 3-12, 2011, bit.ly/19kvVl3. [2] Bielaczyc, P., Pajdowski, P., Szczotka, A. and Woodburn, J., Development of automotive emissions testing equipment and test methods in response to legislative, technical and commercial requirements, Combustion Engines, ISSN: 0138-0346, 1/2013 (152), 28-41, 2013, bit.ly/11EcDCd. [3] Feasibility of Introducing Particulate Filters on Gasoline Direct Injection Vehicles, JRC report 25297 EN, 2011. DOI:10.2788/23375. [4] Eastwood, P., Particulate Emissions from Vehicles, (Chichester, England), 2008. ISBN: 978-0-470-72455-2.