Can existing periodic technical inspection instruments measure GDI engine emissions?

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Periodic technical inspection (PTI) of vehicles is used in several countries, including Switzerland, to detect defective diesel particulate filters (DPF). This is achieved by measuring the particle number (PN) with PN-PTI devices that can be used by non-experts in a garage setting at a relatively low cost. Gasoline direct injection (GDI) engines also have particulate filters that can be damaged or tampered with and therefore, could benefit from PN-PTI inspection. However, existing devices were not designed for gasoline exhaust which tends to have higher humidity and smaller particle sizes compared to diesel engines. Here, we investigate the effectiveness of PN-PTI devices type-examined for diesel vehicles in Switzerland, to detect emissions from GDI engines with simulated and real GDI exhaust. Laboratory experiments were performed with miniCAST soot with geometric mean mobility diameters in the range of 15 – 85 nm with and without added humidity. Field measurements were performed at the European Commission Joint Research Centre (JRC) with six different gasoline vehicles running at low idle, low loaded idle, high idle and high loaded idle.

The geometric mean mobility diameter (GMD) of the particles from the vehicles studied were most commonly in the range from 30 – 60 nm. While all of the devices were able to measure particles in this size range, the counting efficiency (CE) was poor as the 50 % cut-off was also in the GMD range of 34 – 63 nm for miniCAST soot. The raw aerosol from the miniCAST provides a relatively dry aerosol with about 10 % relative humidity at room temperature. All but one of the PN-PTI devices were able to measure at elevated humidity levels similar to that observed in gasoline exhaust. Approximately half of the devices were unaffected by elevated humidity while the other half showed an increase in the CE. The tested PN-PTI devices employed variations of the direct charging (DC) particle measurement principle. Thus, the increased CE suggests that the increased humidity seems to enhance the ability of the DC sensors to detect particles. Therefore, existing PN-PTI devices seem capable of measuring GDI exhaust however, modifications may be necessary to reach an acceptable CE in the size and humidity ranges relevant to gasoline exhaust.

Catalytic oxidation of CO, VOC and PM in O_2-rich exhaust of small-scale fireplaces

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In Germany around 11.5 millions of individual room heating systems such as fireplaces and stoves exist. Many of them use biomass as combustible, for instance wood, which is of importance toward the defossilization of the energy sector. However, incomplete biomass combustion leads to the emission of carbon monoxide (CO), volatile organic compounds (VOC) and particulate matter (PM). In the course of the revision of the Federal Immission Control Regulation ("BImSchV") emission limits for CO (4 g m^{-3}) and PM (0.15 g m^{-3}) were introduced. Oxidation catalysts, which are capable of simultaneously converting these pollutants, are available for new combustion systems and retrofitting. The catalysts are based on cost-intensive precious metals such as platinum (Pt) and palladium (Pd) and require maintenance due to soot and ash residues. Thus, the present contribution reports on our R&D dealing with novel low-cost and self-cleaning Fe-Mn catalysts for the abatement of pollutants in the O_2-rich exhaust gas of small-scale fireplaces.

Bare Fe-Mn oxide samples were systematically developed by varying the Fe/Mn proportions and physico-chemical properties such as crystallinity and porosity. The samples were prepared in-house, physico-chemically characterized and tested in the laboratory in the form as granulated powders (125 - 250 µm). For the catalytic tests, a synthetic exhaust was used composed of 10 vol.% O_2, 10 vol.% H_2O and 250 ppm toluene as a model compound for organic soot. Figure 1 exemplarily shows the oxidation performance of the currently best Fe-Mn oxide catalyst compared with a Al_2O_3-supported Pt/Pd reference catalyst. As a result, both catalysts completely oxidize toluene above 350°C, which of high relevance for an efficient removal of organic matter. Temperatures of 350°C and above appear at the outlet of the combustion chamber. Moreover, the Pt/Pd sample is more active at lower temperature.

Conclusion

Fe-Mn oxide catalysts were investigated toward the lean oxidation of toluene as a model compound for organic particles present in the exhaust of small-scale fireplaces. The precious metal-free catalyst shows a promising oxidation activity at relevant temperatures and offers the possibility to replace state-of-the-art Pt/Pd catalysts. Moreover, the contribution at NPC-25 will report further results of our systematic study on the effect of catalyst properties and exhaust gas conditions on the removal of CO, VOC and PM. Additionally, some up-scaling results will be presented.

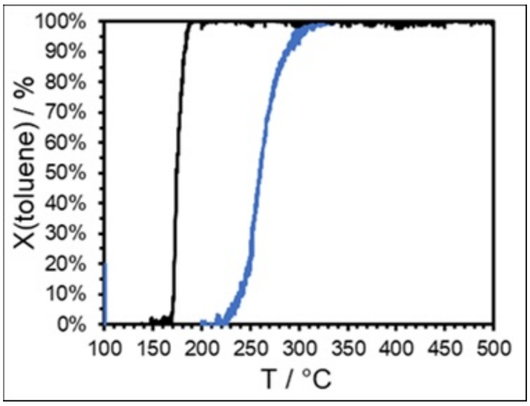

Figure 1: Toluene conversion on Fe-Mn oxide (blue curve) and Pt/Pd reference catalyst (black curve) in lean model exhaust of small-sale fireplace

Influence of electrostatic precipitators at small-scale biomass combustion systems on particle number emissions and particle size distributions

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The harmful effects of ultrafine particles out of biomass combustion provides the background of measurements at different wood combustion systems equipped with electrostatic precipitators. Simultaneously, gravimetric measurements according to VDI 2066 and particle number measurements have been done before and after the precipitators in parallel, using three different types of devices (MPSS, NPET, ELPI®+). To evaluate the comparability of the different measuring devices and the variance, quality assurance and calibration analyses of the measuring devices with aerosol generators and comparison measurements using the measuring devices in one flue gas measuring section during operation of a wood log stove have been carried out. Beside of the particle number changes induced by a precipitator also those in the flue gas pipe without the electrostatic influence were analyzed.

The ELPI devices showed the highest particle number concentrations, followed by MPSS and thereafter the NPET devices, due to the different measurement principles and as well size ranges covered. The measurement data shows the reduction of the particle number concentration (15-50 %) in course of the flue gas pipe accompanied by a shift of the particle size distribution to bigger particles. The observations are reasoned by agglomeration and coagulation and as well deposition at the pipe walls. The electrostatic precipitators were able to reduce the number of particles by more than an order of magnitude in some cases. However, the reduction was different for the various combinations of furnace and separator. The investigations provide a data basis for several aspects like the impact of precipitators on particles as well as the assessment of operating condition based on gravimetric and particle number measurements.

Reducing fleet emissions by periodical technical inspection

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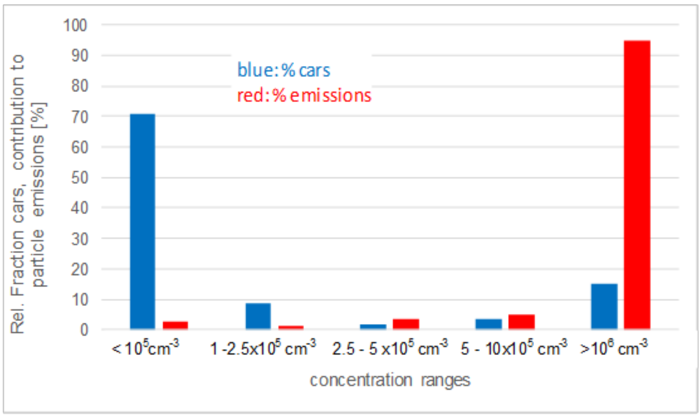
Particle emissions from diesel engines, equipped with properly working particle filters are very low, often lower than ambient concentrations. However, small cracks or manipulations may lead to emitted particle concentrations, which are orders of magnitudes higher. A number of studies from different countries demonstrate the severity of this problem. Recent studies show that the situation is very similar for gasoline engines. As an example Figure 1 shows the fraction of cars and their contribution to emissions in 5 concentration ranges. It is very obvious that most cars a clean and a small fraction is responsible for most emissions. We call this the ‘dirty tail paradigm’. A summary of several studies is shown in Figure 2. There the average emissions of all cars are compared those of the cars below a limit of 250’000 cm^{-3}. Emissions of cars, fulfilling this limit are more than an order of magnitude lower.



These high polluters have to be identified and one option therefore is a periodic technical Inspection (N-PTI) of the PN-emissions. At least for diesel engines a simple measurement at low idle is well correlated with results from type approval testing. For gasoline engines this correlation is not as good, there more work is needed. In several countries PTI meanwhile has been introduced, at least for diesel engines.