Simple periodic DPF testing with a handheld device

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Motivation

Diesel particle filters remove 99% or more of the particles produced by the engine. However, the filters may be damaged in use, leading to highly polluting vehicles. Here, we show that testing filter integrity in the field can be extremely simple.

State of the art

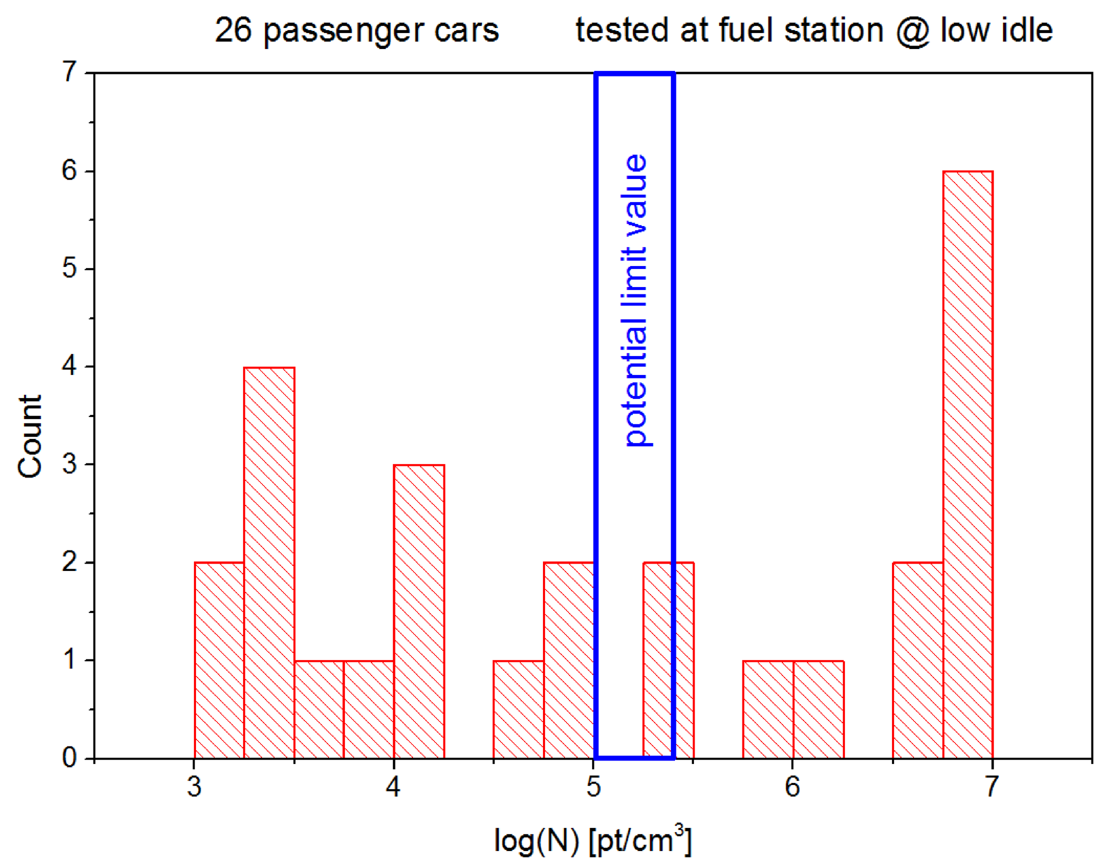
There already exist dedicated instruments to verify DPFs in the field which try to mimic the PMP protocol applied in type approval. These devices are bulky and expensive, as the PMP method was introduced with laboratory measurements in mind. In two recent reports, scientists of TNO have checked DPF integrity with handheld condensation particle counters, without any exhaust gas conditioning [1,2]. Dilution is avoided by measuring at low idle, where Diesel engines have very high air-to-fuel ratios (λ~10) so that the exhaust gas is automatically diluted. Still, they recommend that *"to measure higher PN concentrations, sample dilution with a factor 10 is advised"* - since the CPCs can only measure relatively low maximal concentrations (1-5·10^5 pt/cm^3).

A better alternative

We propose that DPF testing should be done with diffusion chargers (DC) instead of CPCs. The advantages are: DCs are easier to use (no working fluid), unsensitive to ambient temperatures, can be held in any orientation, and their measurement range fits the application perfectly, making the recommended secondary 10:1 dilution unnecessary. The only apparent problem is that they don't measure a particle number.

DC uncertainty

The signal S of the DC is given by $S \sim N \cdot \bar{d}$, the number concentration multiplied by the average particle diameter. N can be determined if $\bar{d}$ is known. If the device is calibrated for $\bar{d}$ = 70 nm, then for typical diameters of 50-100 nm, the device will have a maximal uncertainty of about 40%, which is actually not much worse than the full PMP type approval test, for which reported uncertainties are around 25%.



Implementation

We modified a miniature portable diffusion charger, the naneos partector, for DPF field inspection. The only two modifications necessary were

- a 30 cm long steel inlet tube
- An internal heater to heat the device to about 10 °C above ambient temperature to prevent issues with water condensation

When calibrated to particle number concentration at 70 nm, this device has a range of about 300 - 6·10^6 pt/cm^3 which is perfectly suited to the application, where a limit value somewhere around 10^5 pt/cm^3 has been suggested. Thanks to an integrated humidity sensor, potential issues with water condensation can easily be detected.

Field test

To verify the method, we used our device during a two-hour interval at a fuel station. Every driver stopping at the Diesel pump was asked to participate, and in total, 26 Diesel passenger cars (with and without filter) were tested. The partector was used to measure the exhaust gas at low idle for about 20 seconds for each car. No problems occurred throughout the entire measurement series, and the maximal RH measured in the device reached 80%.

Results

The measured concentrations of all 26 cars are shown in the histogram beside. At least one car whose driver claimed it had a filter fell into the category of polluting cars. For four cars without DPF the maximal concentration of the device was reached.

Conclusions

We have demonstrated that it is very easy to verify DPF integrity in the field with a robust and cost-effective method, that is commercially available today and sufficiently accurate for the purpose. In our view, regulation today focuses too narrowly on particle number only, and has lost sight of the overall purpose, namely to improve air quality and public health by making efficient DPF field tests possible.

[1] G. Kadijk et al. TNO report TNO 2017 R10530
[2] G. Kadijk et al. TNO report TNO 2016 R10735