GAS ADSORPTION EFFECTS IN PARTICULATE FILTERS

Michael Arndt, Wolfgang Schindler (AVL List GmbH), William Silvis (AVL NA Inc.)

The PM mass collected over a test cycle from modern DPF equipped diesel vehicles is usually extremely low. It is very well known that in such cases the background effects, which are observed when sampling PM on a filter, have a significant impact on the accuracy. The background PM, which usually is highly variable, can amount to 50% or more of the PM filter weight. Gas adsorption effects contribute to the loadings of filters used for engine particulate emissions testing and homologation [Chase, Khalek, Vogt, Giechalskiel]. The effect was negligible for pre-2000 Diesel engines. In post-DPF emissions testing the gas adsorption effect constitutes a substantial fraction of the filter loading. Beside the chemical nature of the adsorbed species, the amount of adsorption is influenced by various factors like temperature, face velocity and filter material.
We have investigated the following points:

1) Adsorption probability of typical exhaust components
2) Adsorbed mass versus time – saturation effects
3) Filter area and filter material effects

All tests presented here were carried out under Steady-State conditions (constant flow and concentration). As a model Hydrocarbon (HC) mixture the filtered exhaust of a CAST burner was used (200ppm C_3H_8 according to FID analysis). Different HC compositions will likely show different adsorption effects.

Adsorption probability – saturation effects

Figure 1 shows the adsorption of HC and NO_2 on TX40 filters. The adsorption probability of (dry) NO_2 is found to be very large. The adsorption probability of NO_2 increases dramatically with increased humidity. NO shows much lower adsorption (not shown). The adsorption probability of HC is much smaller compared to NO_2. Both species show a saturation effect (also observed in real-world In-Use testing). Front and backup filters have practically the same adsorbed mass.

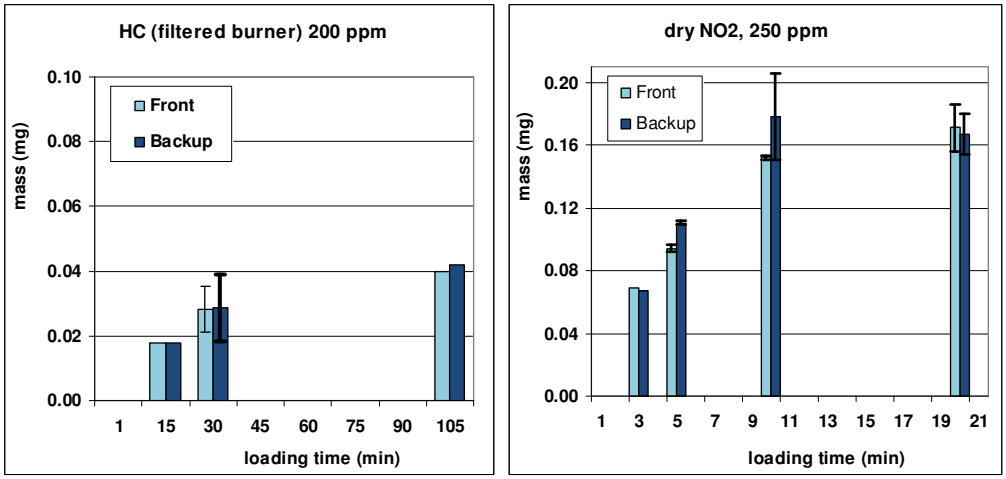

Figure 1: Adsorption of NO2 and HC on TX40 Filters – Saturation effect

Effect of reducing the filter area

A reduction of only the front area has practically no effect on the mass adsorbed. This can be expected because the adsorption can take place from the backside of the filter, which is exposed to the gas as well. Covering front and back of the filter reduces the mass substantially (Figure 2). The (increased) filter face velocity is not the dominant effect. This was investigated in separate experiments. NO_2 shows qualitatively the same effects like HC.

Influence of the filter material

For both, NO_2 and HC, the adsorption by a Teflon filter is substantially smaller than by TX40 filters, as can be seen in Figure 2.
The use of Teflon filters and the reduction of the filter area show comparable reductions of the adsorbed mass.

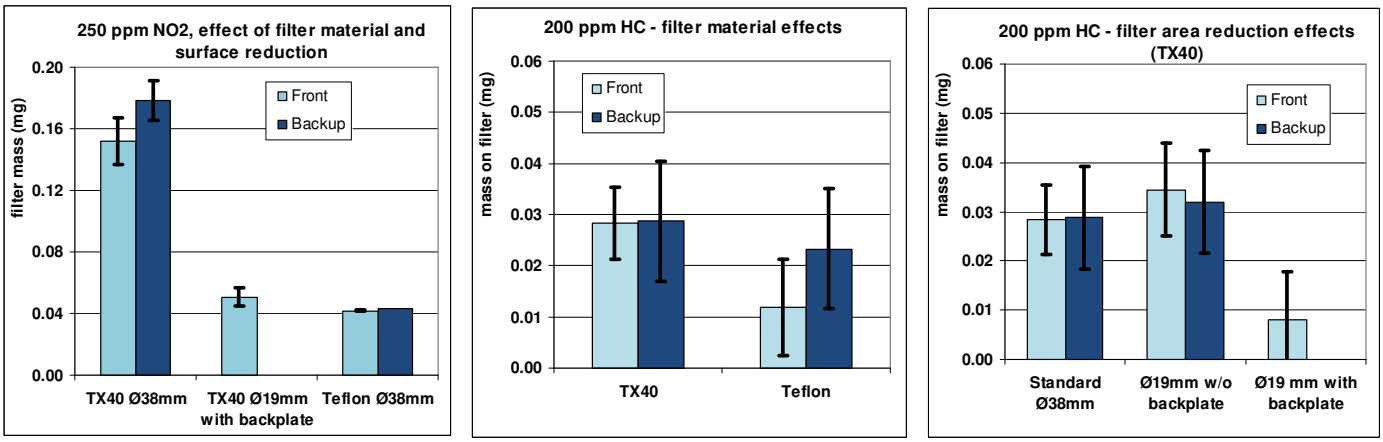

Figure 2: Effect of filter material and filter surface area on adsorption

Conclusions

By reducing gas adsorption effects a lower limit of meaningful gravimetric particulate emissions measurements can be achieved. Methods like reducing the filter surface area or using Teflo filters instead of TX40, help to minimize gas adsorption.
The gas adsorption effect has been investigated for immission particulate measurements [McDow, Turpin] as well. There it is common practice to subtract the loading of a backup filter from the front filter loading to obtain airborne particulate concentrations. This could also be done for emission measurements, since in all performed tests the amount of adsorption on front- and backup-filter was the same.
Especially for filter-based PM-PEMS instruments this technique would mean an improvement. These instruments use different flow rates and dilution ratios than lab instruments. Therefore each instrument may show different levels of adsorption on the same exhaust. Removing the adsorption artifact either way would help to push the limits to lower values. Accuracy and comparability at very low PM levels can be increased significantly.

References

Chase, R. E. et al, SAE Technical paper 2004-01-0967.
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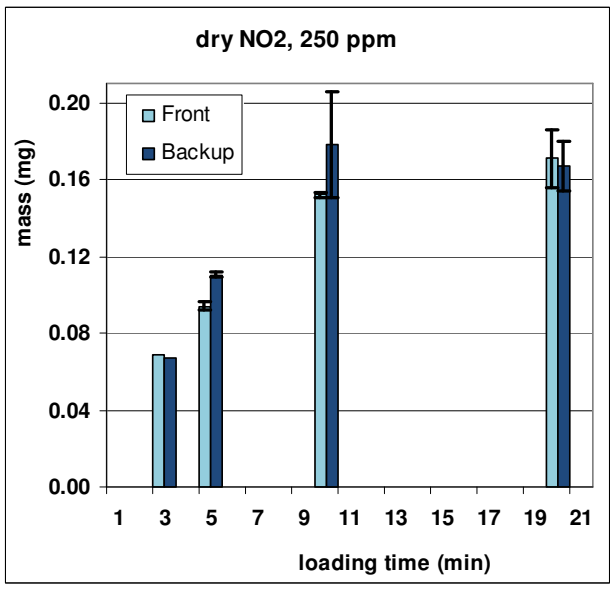
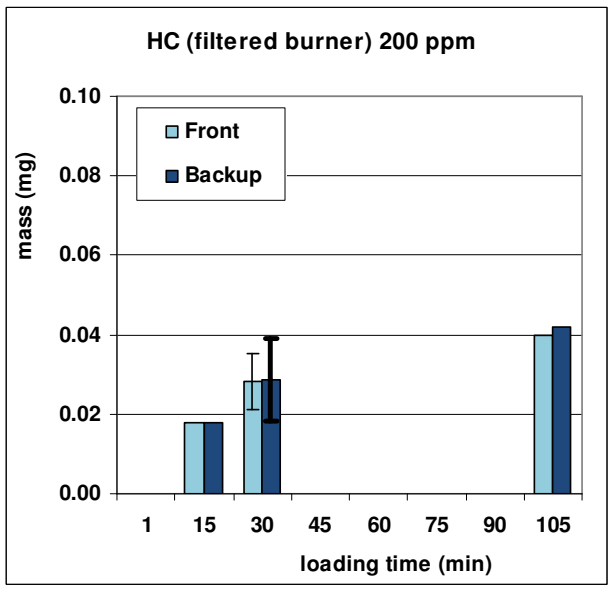
Gas adsorption effects contribute to the loadings of filters used for engine particulate emissions testing and homologation [Chase, Khalek, Vogt, Giechalskiel]. The effect was negligible for pre-2000 Diesel engines. By now, Diesel particulate Filters (DPF) are a widely used, and the particulate emissions after such devices are close to ambient. The gas adsorption effect therefore constitutes a substantial fraction of the filter loading in post-DPF emissions testing.
The gas adsorption effect has been investigated for immission particulate measurements [McDow, Turpin], where it is common practice to subtract the loading of a backup filter from the front filter loading to obtain airborne particulate concentrations. We have investigated some of the open questions:

- Adsorption probability of typical exhaust components
- Adsorbed mass versus time – saturation effects
- Filter area and filter material effects

We present the results of a first test series. Further investigations and a theoretical interpretation are due to follow in the future.

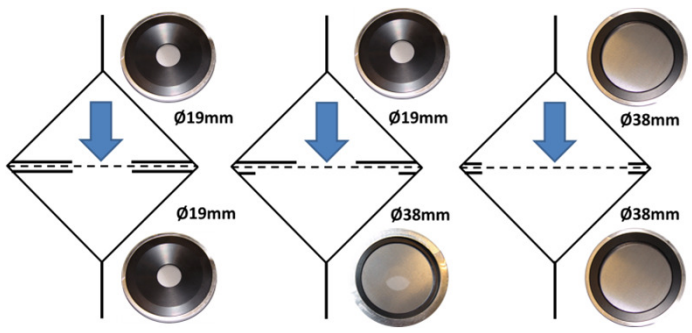
Adsorption probability – saturation effects



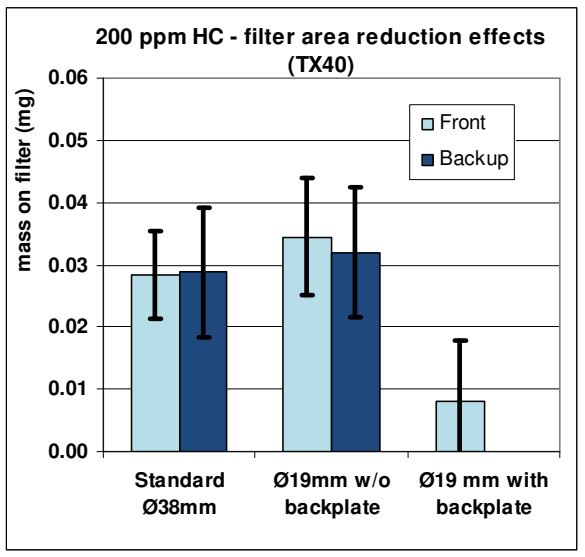


- The adsorption probability of (dry) NO_2 is very large on TX40 filters.
- The adsorption probability increases dramatically with increased humidity (not shown)
- NO shows much lower adsorption (not shown here)
- The adsorption probability of HC is much smaller
- Both substances show a saturation effect (also observed in real-world InUse testing.
- Front and backup filters have practically the same adsorbed mass

Effect of reducing the filter area



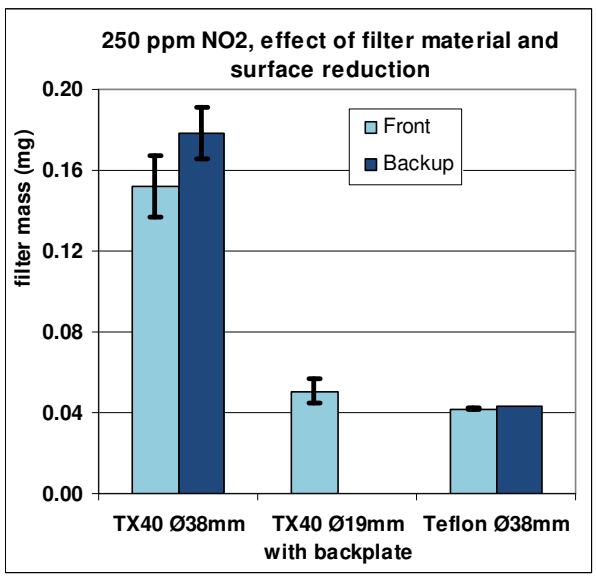
- A reduction of only the front area has practically no effect on the mass adsorbed
- This can be expected because the adsorption can take place from the backside of the filter, which is exposed to the gas as well
- Covering front and back of the filter reduces the mass substantially
- The (increased) filter face velocity is not the dominant effect.
- NO2 shows qualitatively the same effects like HC.

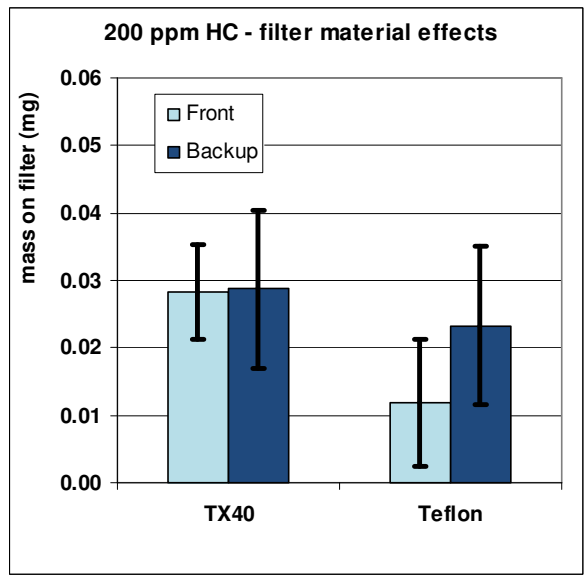


Influence of the filter material

- For both, NO_2 and HC, the adsorption by a Teflon filter is substantially smaller than by TX40 filters.
- The use of Teflon filters and the reduction of the filter area show comparable reductions of the adsorbed mass

With the reduced gas adsorption effects a lower limit of meaningful gravimetric particulate emissions measurements is achieved.





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