BMW Dieselmotorenentwicklung

Some aspects for future particulate measurement

1. Gravimetric mass measurement

2. Particulate size distribution
   some influences on the test results

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Some aspects for future particulate measurement

1. Gravimetric mass measurement

By our experience the gravimetric mass measurement is quite good for being used at emission levels of EU-4 and below. To estimate the lower limit of this method BMW did the following investigation.

To get a very low particulate loading, blank-test had been carried out. Instead of sampling the exhaust of a vehicle the air of the test-cell had been sampled during a MVEG test. The results are shown in Figure 1 - each five tests had been made on two chassis dynos. As the patterns show the emission decreases with increasing testnumber. We assume that particles are removed from the surface of the sampling system and in time this “particle-source” decreases.

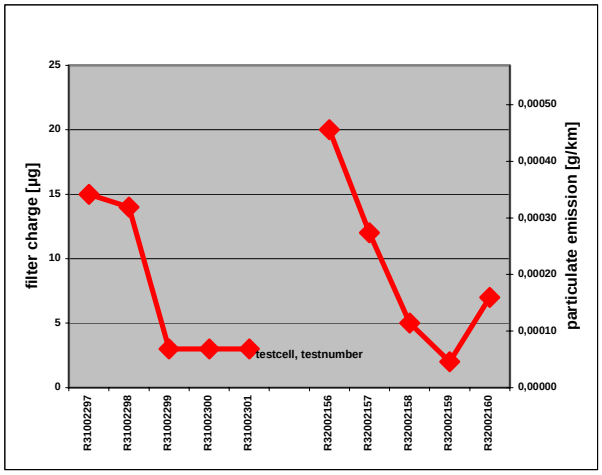

Figure 1: Blank-tests on two chassis dynos

The mean value of all 10 tests is 0,0002 g/km with a standard deviation of 0,00015 g/km. One part of this relatively high standard deviation results from the decreasing “particle-source”. Compared with the EU-4 limit of 0,025 g/km this standard deviation of 0,00015 g/km is less than 1% of that limit value. Tests with very low emission vehicles had smaller standard deviations of about 0,0001 g/km.
The evaluation of the daily weighted reference filters and reference mass results in a deviation of +/- 0,005 mg, this is 2% of a low filter loading of 0,25 mg.
These results corresponds well with the results of Volkswagen AG [1], so we can confirm the statements of this paper regarding the gravimetric mass measurement.

Statement

By our point of view the gravimetric measurement of the particulate mass emission is up to now the only one method, which is suitable to limit values of EU-4.
With some improvements e.g. filter balance with more accuracy, higher gas velocity across the filter, we see a potential for even a lower measuring range.

Reference:

[1]: Bechmann, Carli, Engeler, Garbe, Lach, Ryan, Schindler
Particulate emissions and their measurement in practice: Today and in future
Forum Partikelemissionen 24./25.10.2002, Nürnberg p. 33-51

2. Particulate size distribution - some influences on the test results

BMW had made investigations for the determination of particulate size distributions. In the following figures some effects are shown how test results may be influenced by

- Nucleation
- Sulphur content of the fuel
- Sampling system and samplingpoint

The particulate size distribution was measured with a twin SMPS with a Faraday-Cup Electrometer from the University of Vienna, Prof.Reischl.
Tests had been carried out on an engine test bed with a BMW Diesel engine M47 (2 lit., 110 kW / 4000 rpm). The operating point was 2400 rpm and 7 bar pme corresponding to a vehicle speed of 120 km/h.

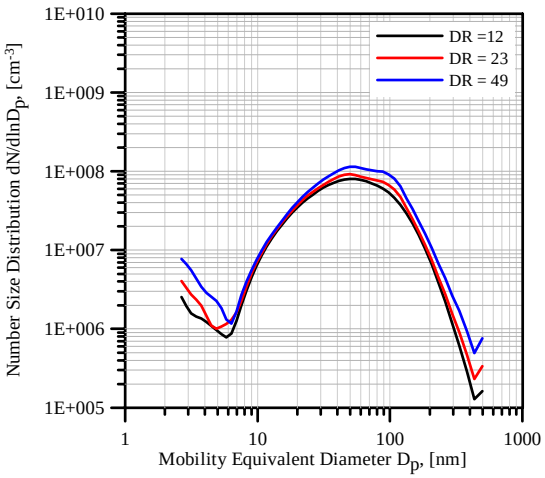

Fig.2: variation of dilution ratios, sampling point in front of catalyst, temperature 40°C, 210 ppm sulphur

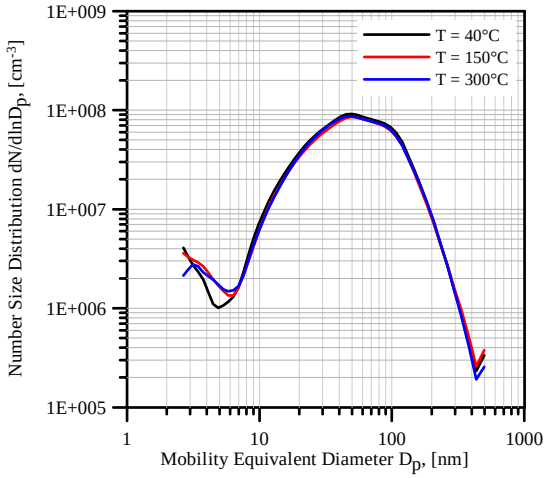

Fig.3: variation of temperature, sampling point in front of catalyst, dilution ratio 23, 210ppm sulphur

Figure 2 shows the size distribution with the sampling position in front of the catalyst, the fuel is standard diesel with 210 ppm sulphur. The measurements had been made with three different dilution ratios of 12, 23 and 49. It can be seen, that the three results are nearly the same and that there is no influence of the dilution ratio.

Figure 3 shows the result of the same setup with a dilution ratio of 23 but varying the sample temperature of 40°C, 150°C and 300°C. The results are identically, that means that in this case there is no influence of the sampling temperature.

In Figure 4 the sampling position is behind the catalyst. The monomodal distribution changes to a bimodal distribution with a sharp peak in the range of 5 to 20 nm. Additionally the shape of this peak depends on the dilution ratio.

Figure 5 has the same setup as Figure 4, but at these tests the sampling temperature was varied at constant dilution ratio of 23. In this case, the shape of the peak depends on the sampling temperature and the nucleation process becomes more complex.

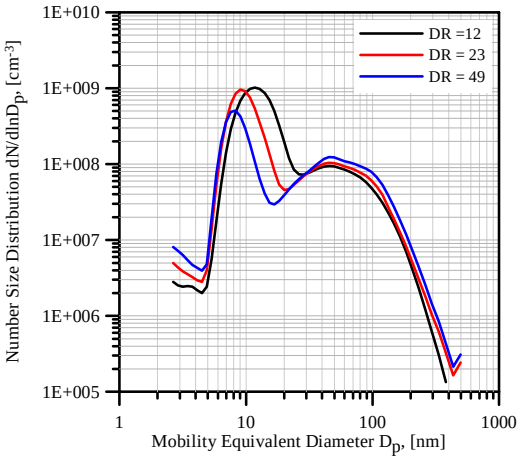

Fig.4: variation of dilution ratios, sampling point behind catalyst, temperature 40°C, 210 ppm sulphur

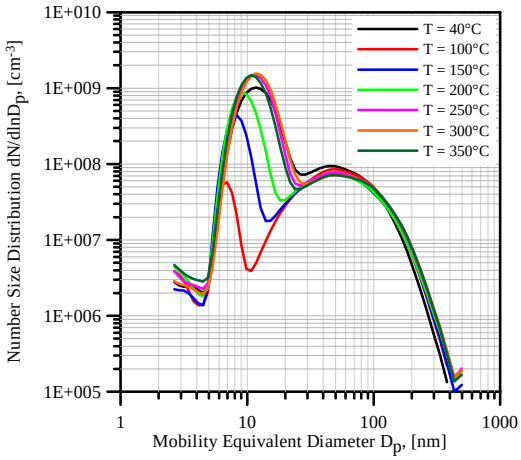

Fig.5: variation of temperature, sampling point behind catalyst, dilution ratio 23, 210ppm sulphur

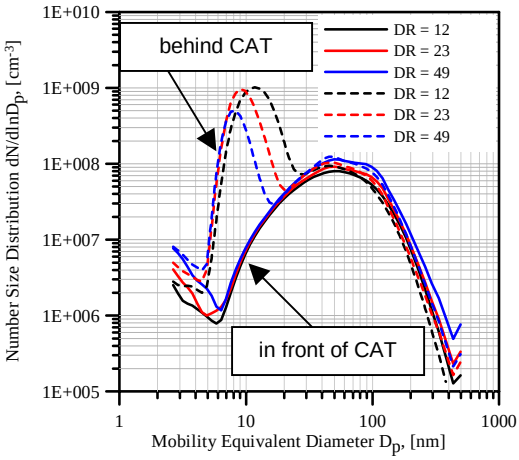

Fig.6: variation of dilution ratios, sampling point in front and behind catalyst, temperature 40°C, 210 ppm sulphur

Figure 6 shows the results of Figure 3 and Figure 4 for an easier comparison. In the range above 30 nm the shapes of sampling in front and after the catalyst are nearly the same, below 30 nm the nucleation effect can be seen very clearly.

Figure 7 has the same setup as Figure 4 but using a low sulphur diesel with 10 ppm. Though the sampling position is behind the catalyst in this case no nucleation can be observed.

Figure 8 shows a variation of sampling temperature. In this case there is also no nucleation being observed.

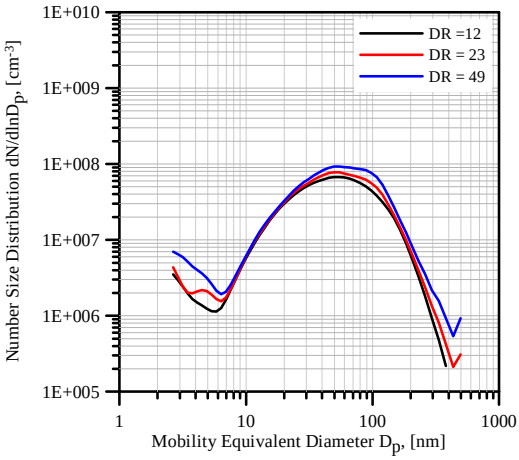

Fig.7: variation of dilution ratios, sampling point behind catalyst, temperature 40°C, 10 ppm sulphur

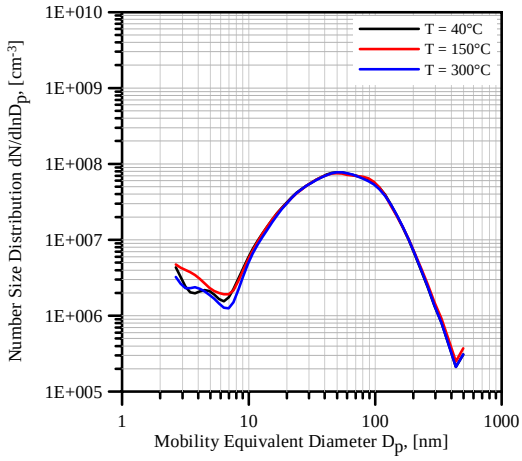

Fig.8: variation of temperature, sampling point behind catalyst, dilution ratio 23, 10ppm sulphur

sampling position / catalyst	dilution ratio	sampling temperature	sulphur in the fuel	Fig. No.
in front	12, 23, 49	40 °C	210 ppm	Fig. 2
in front	23	40, 150, 300 °C	210 ppm	Fig. 3
behind	12, 23, 49	40 °C	210 ppm	Fig. 4
behind	23	40 to 300 °C	210 ppm	Fig. 5
in front / behind	12, 23, 49	40 °C	210 ppm	Fig. 6
behind	12, 23, 49	40 °C	10 ppm	Fig. 7
behind	23	40, 150, 300 °C	10 ppm	Fig. 8

Table 1: Test-Matrix

Conclusion

The determination of particulate size distribution may be affected by

Nucleation
This effect arises at sampling positions behind the catalyst and can be observed at the exhaust tailpipe and also at the standard particulate sampling position of a CVS-System.

Sulphur
Especially those fuels with higher sulphur content cause the nucleation process. This influences the shape of the size distribution dramatically and increases the total number of particulates being measured.

Sampling system
Sampling position, sampling system, sampling temperature and dilution ratio may affect the shape of the size distribution and the total number beeing measured.

Statement

By our point of view are systems for particulate size determination **not suitable** for a **quantitative determination** of the particulate emission in connection **with legal limit values**.
The reasons for this statement are

- as shown above, the results may be affected e.g. by nucleation, fuel, sampling system
- today there is no method known for an absolute calibration of particulate size distribution measurement systems.

In our opinion the determination of the particulate size distribution is a good procedure in the **development process** of diesel engines for the **qualitative** assessment of measures in the field of the particulate emission.