Fachhochschule Braunschweig/Wolfenbüttel
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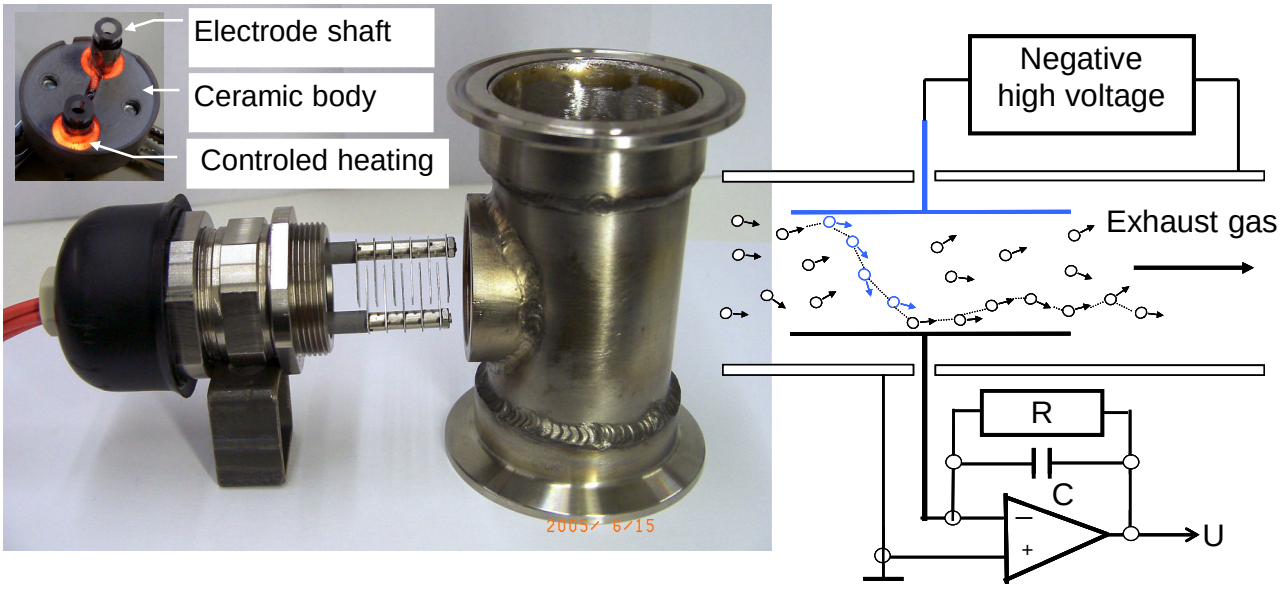
Smoke particle sensors for OBD and high sensitive measurements

Introduction

1. Soot charging sensor for OBD, approved sensitivity: 10 µg/m³ at 4 [s] rise time
2. Soot charging sensor as a measuring instrument of high precision for particle trap inspection. Detection limit: 10 µg/m³
3. Soot charging sensor for investigating engine combustion processes

1. Soot charging sensor for OBD

Operating principle:



Soot particles are attracted by Coulomb forces on to the high voltage plate and receive there a strong charge whilst touching it. As the polarity is equal the particles are repelled on to the virtually grounded plate. The DC- coupled charge amplifier measures the charge of the particles they have transported.

Particles which cannot touch the electrode because of their small size and the high exhaust-gas speed supply a displacement current during crossing the capacitor which also give a contribution to the measured signal.

The significant difference to other soot charging methodologies consists of avoiding corona which ionises other gaseous components of the exhaust gas causing cross sensitivities.

The average value of the voltage U represents the mass of the particles independent from their size. Though the charge sits on the surface the result correlates 97 % to the gravimetric method.

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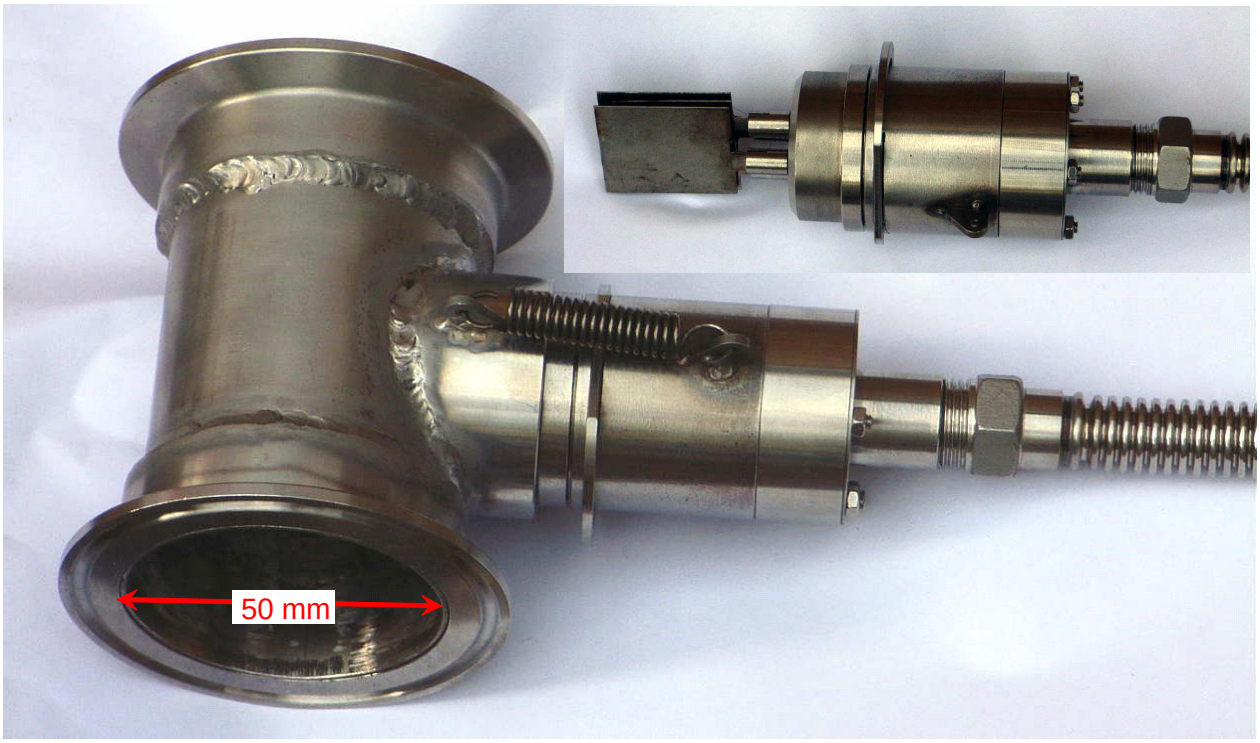
The output signal is depending non linear on the gas flow speed. For OBD applications the gas speed value is calculated from the intake air flow and the fuel consumption, available from the engine control unit, and the temperature inside the sensor.

The most important demand for continuous operation consists of a stable high insulation resistance of the electrode shafts of about 50 [MΩ] at all operating temperatures.

The patented device which gives the solution to this demand consists of an electrode shaft heating keeping the temperature at a constant value, in order to use the effect of thermophoresis.

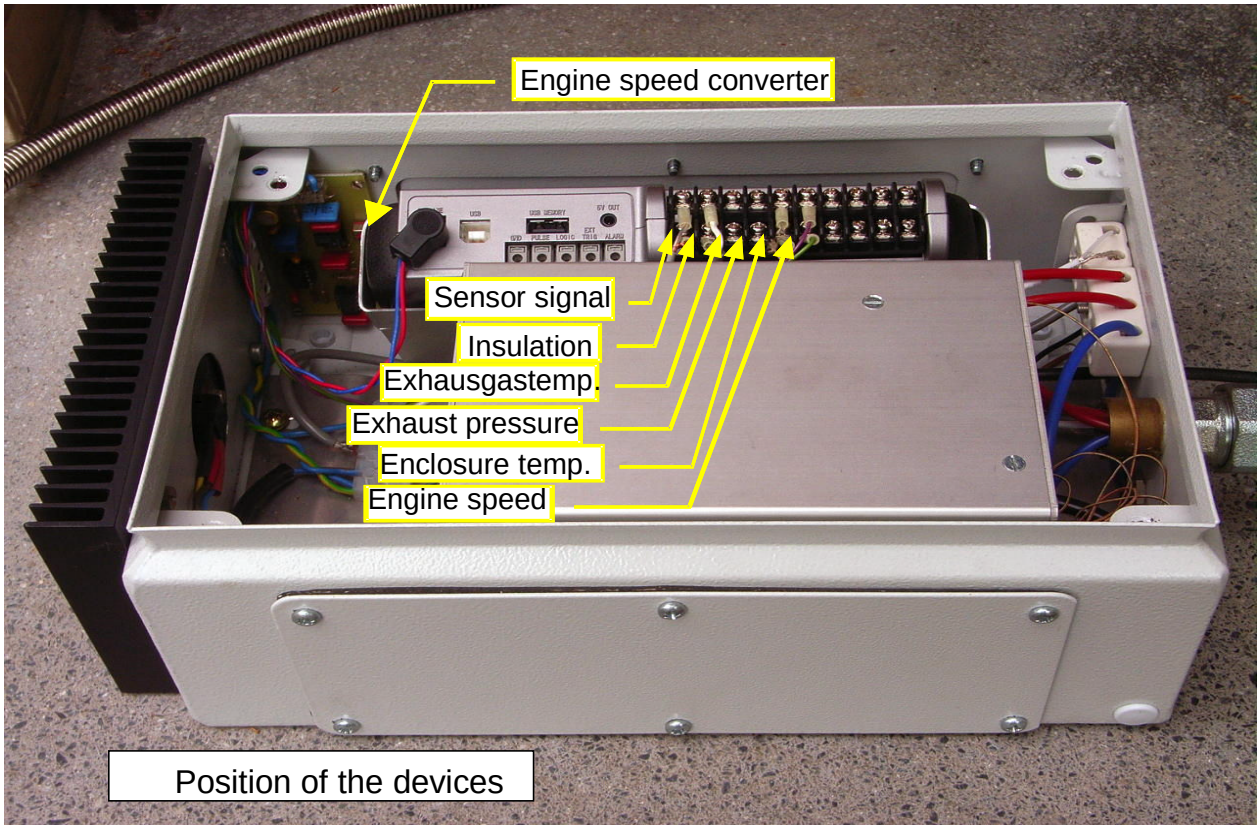
OBD / OBM Measurements of vehicles and non- road applications

The photo shows a new design of the charge sensor for OBD operation in heavy duty applications like caterpillars and other non- road machines. A very robust construction with have less effect on throttling the gas flow.

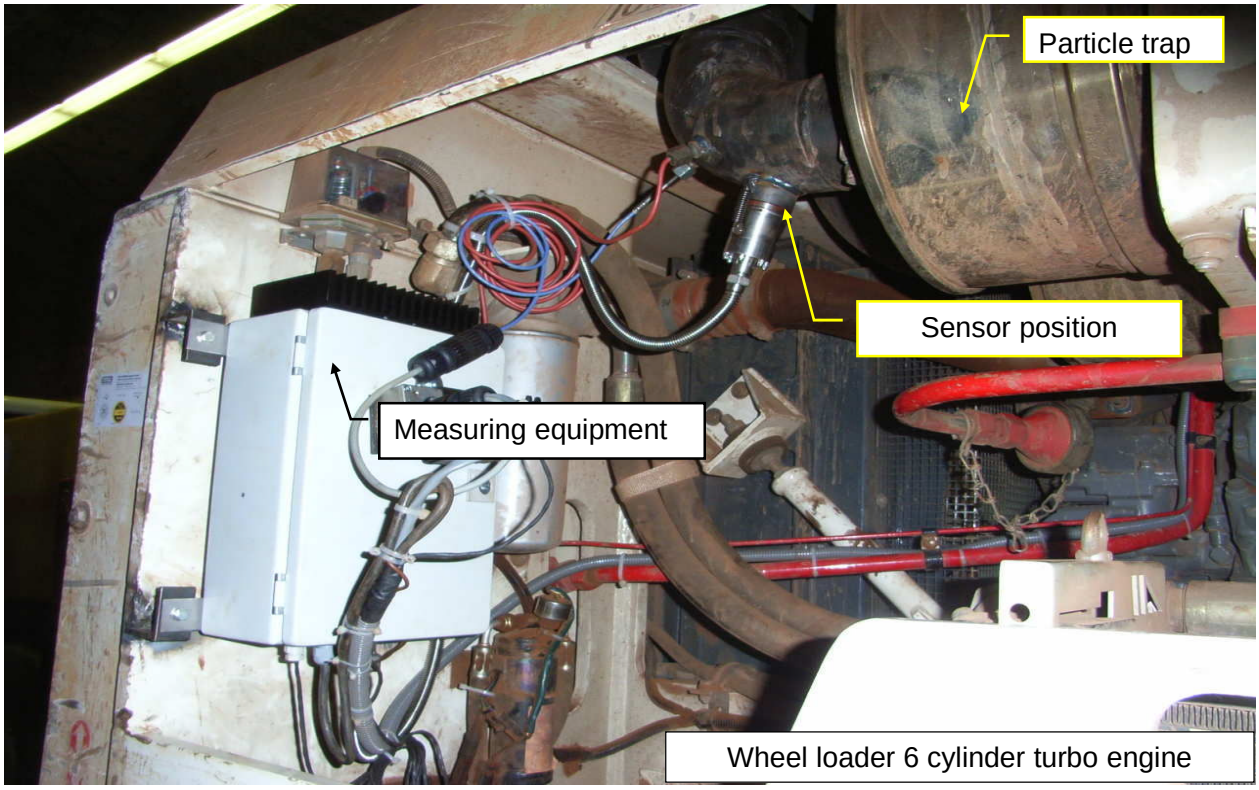


In heavy duty machinery and non road applications it is mostly not possible to get the necessary information for calculating the exhaust-gas speed. In this case specific engine operating points are used for measuring a calibrated smoke emission, like full-load condition. For identifying this operation mode the engine speed, derived from the generator impulses, and the exhaust gas temperature are measured.

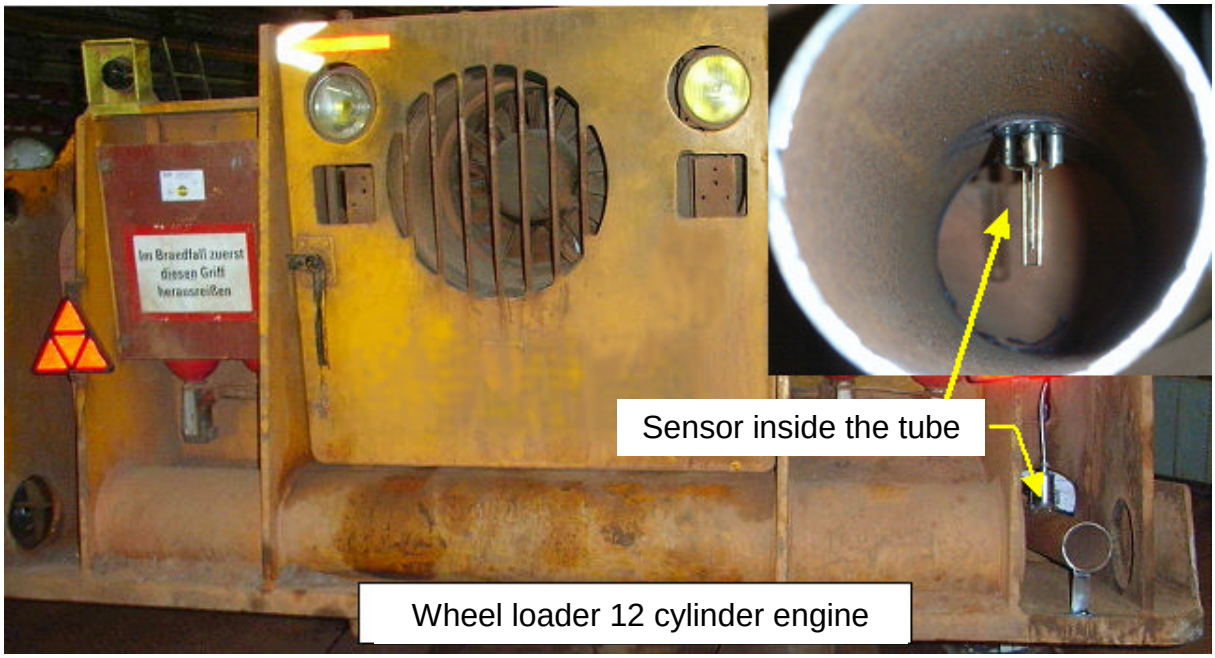
These devices are incorporated into an enclosure together with a data logger for continuous OBD particle trap investigation.



Position of the devices

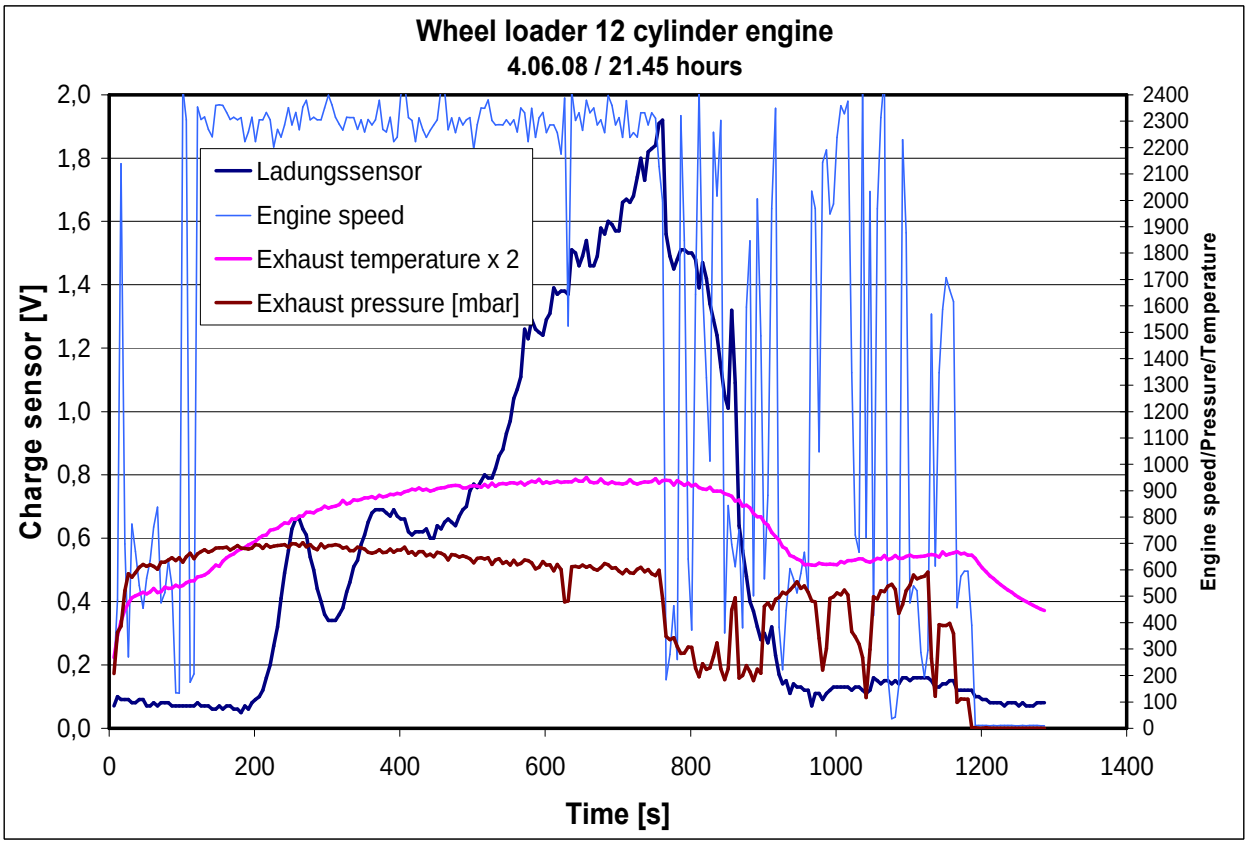


Wheel loader 6 cylinder turbo engine



These tests are organised and sponsored by FAD, Dresden, beginning February 2008 terminating in August. During this time the sensors were night and day in operation under very heavy surrounding conditions. The temperature inside the electronic enclosure reaches values up to 73 [°C]. During that period of observation OBM particle trap regenerations could be measured. As the efficiency of the filter was extremely high – there was no dust during all the 7 months inside the exhaust tube- the integration time of the measuring electronic has to be expanded to 4 [s] in order to collect enough particles.

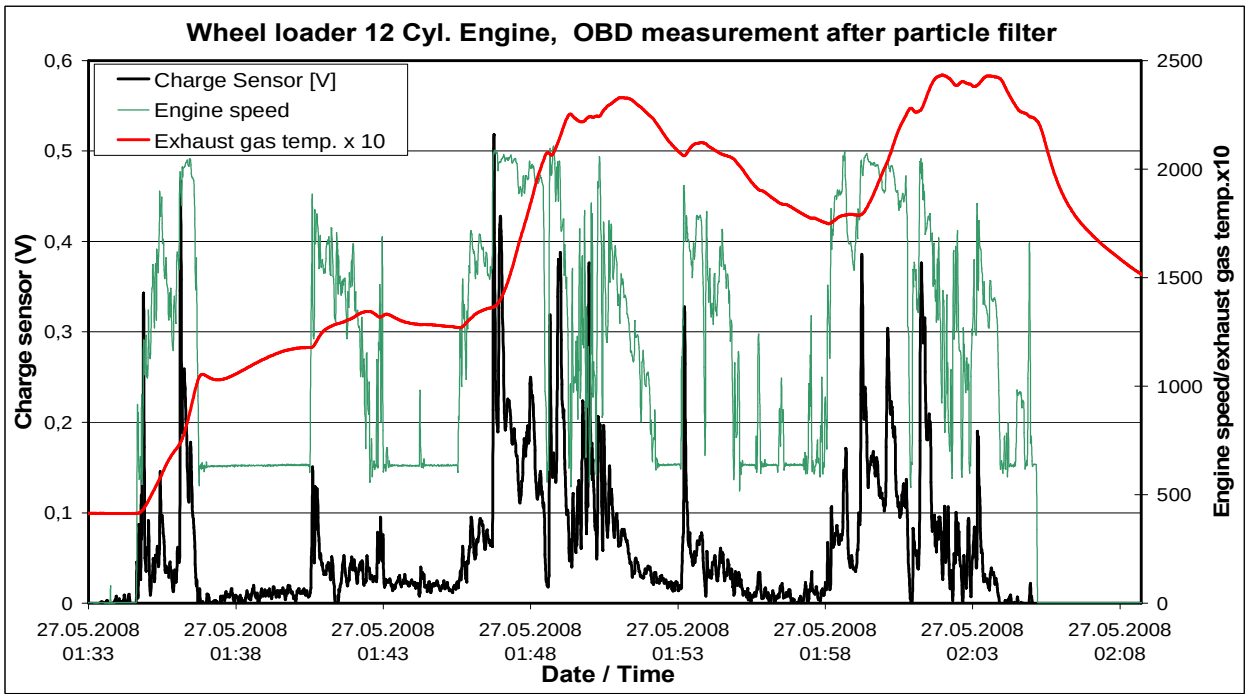
The next diagram shows a sample of a OBD particle trap regeneration.

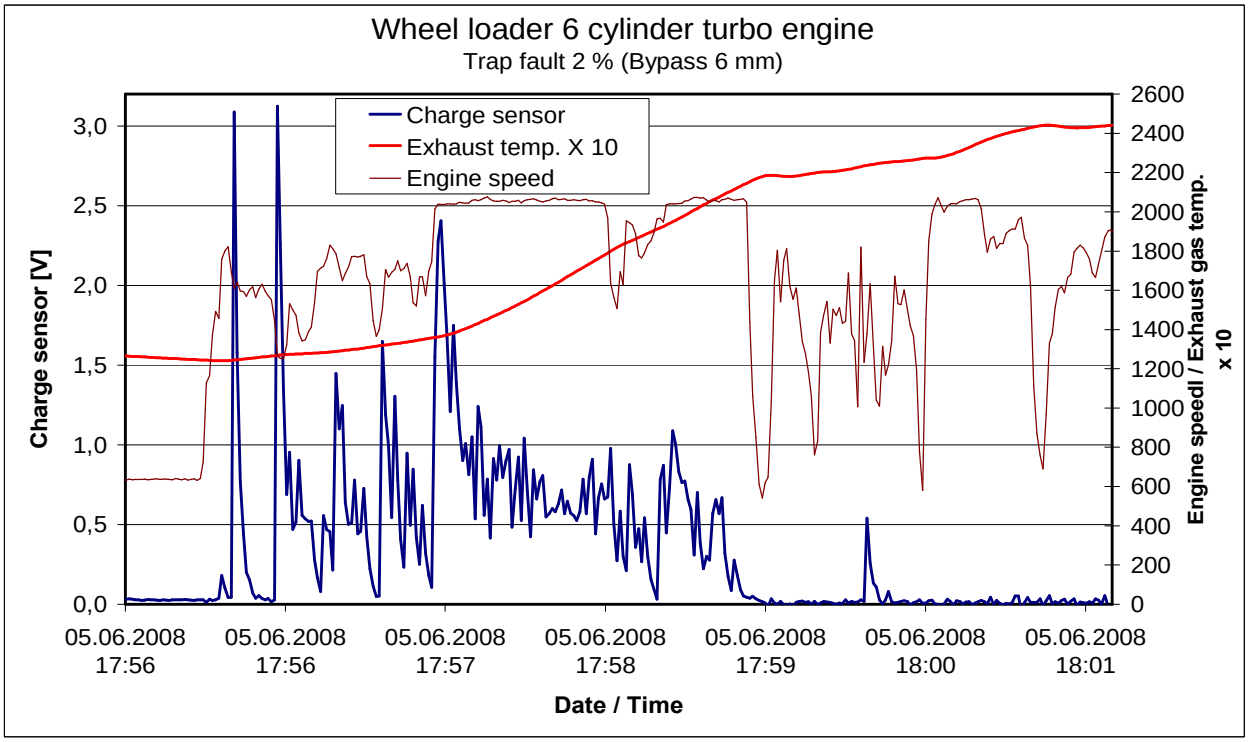


During this procedure the emission rises by factor 19 from 0,1 [V] up to 1,9 [V].

The normal operation shows the typical emission behaviour. At continuous exhaust gas temperature and high engine speed a low emission occurs because the wheel loader runs down a hill. High engine speed and a high temperature gradient demonstrates a full- load engine operation followed by high emissions up to 0,4 [V] sensor output.

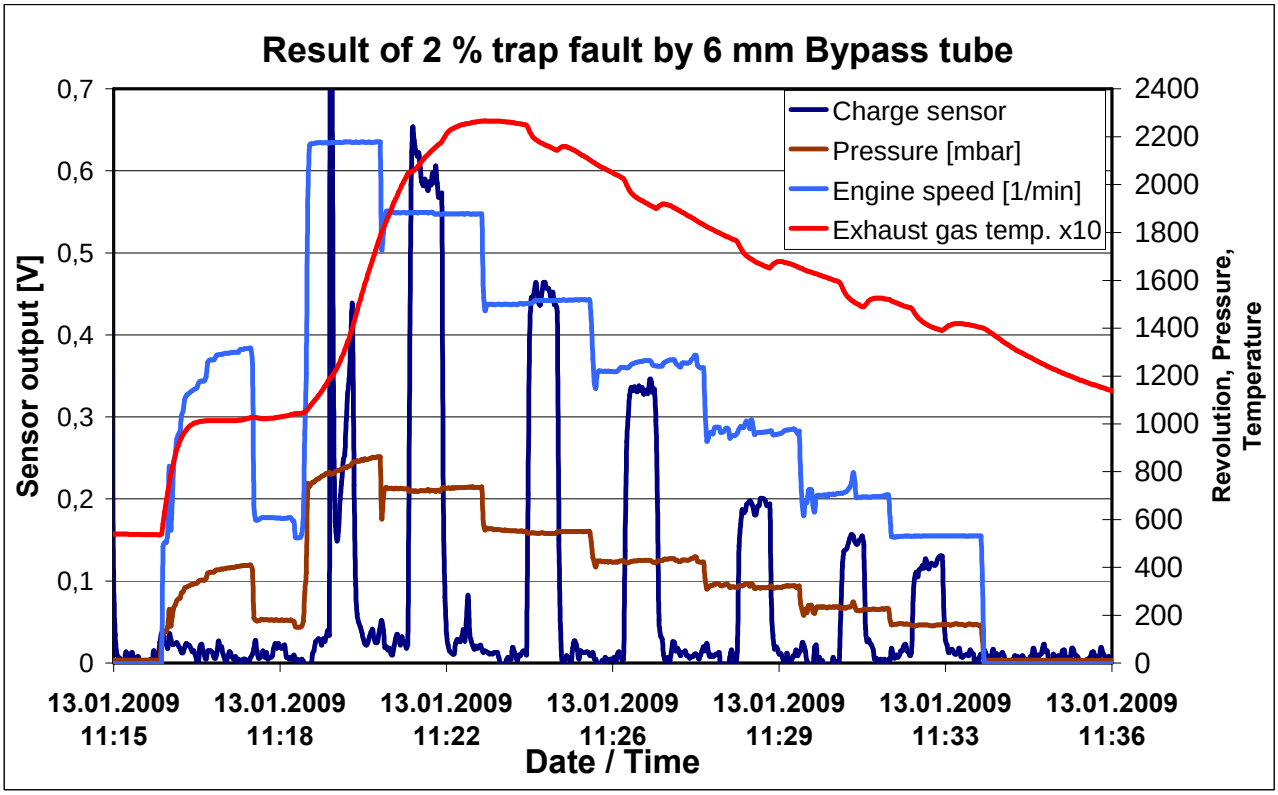
In the following diagram a fault of the filter of about 2 % was simulated by using a by pass tube of 6 [mm] diameter crossing the particle trap. Comparing the two diagrams it can be seen that the signal rises from 0,4 to 3 [V] output.





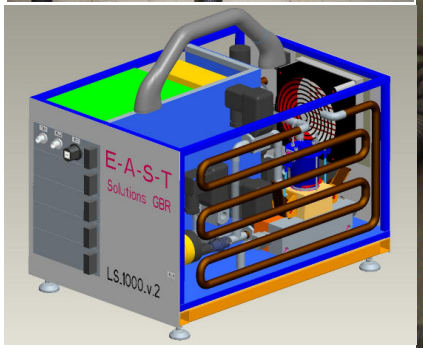
The temperature gradient rises very slow because of the property of the temperature device.

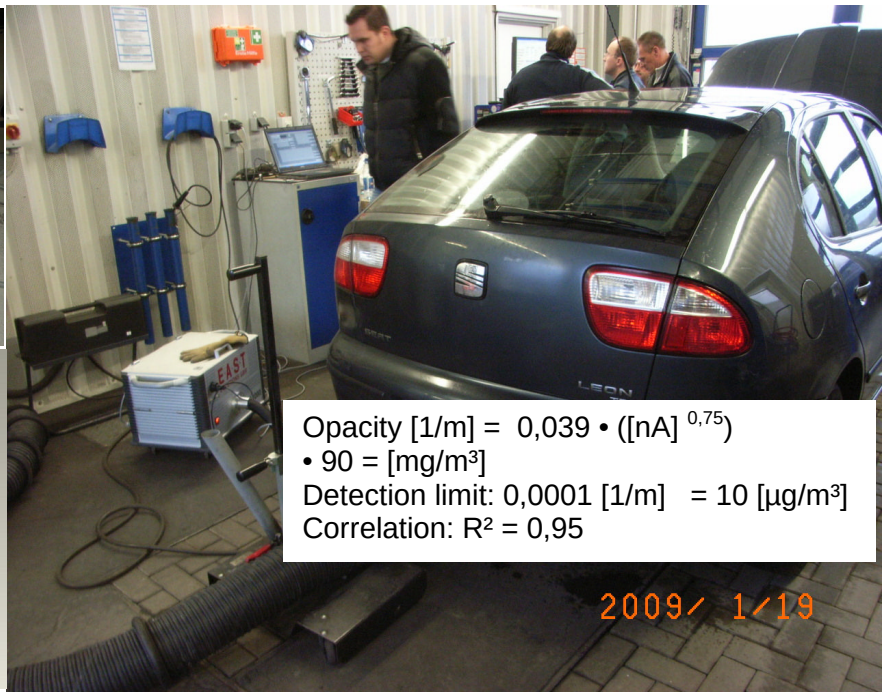
The next diagram demonstrates the possibility of a particle trap investigation at non-load engine but with different engine speeds. The by-pass tube could be closed and opened by a ball valve.



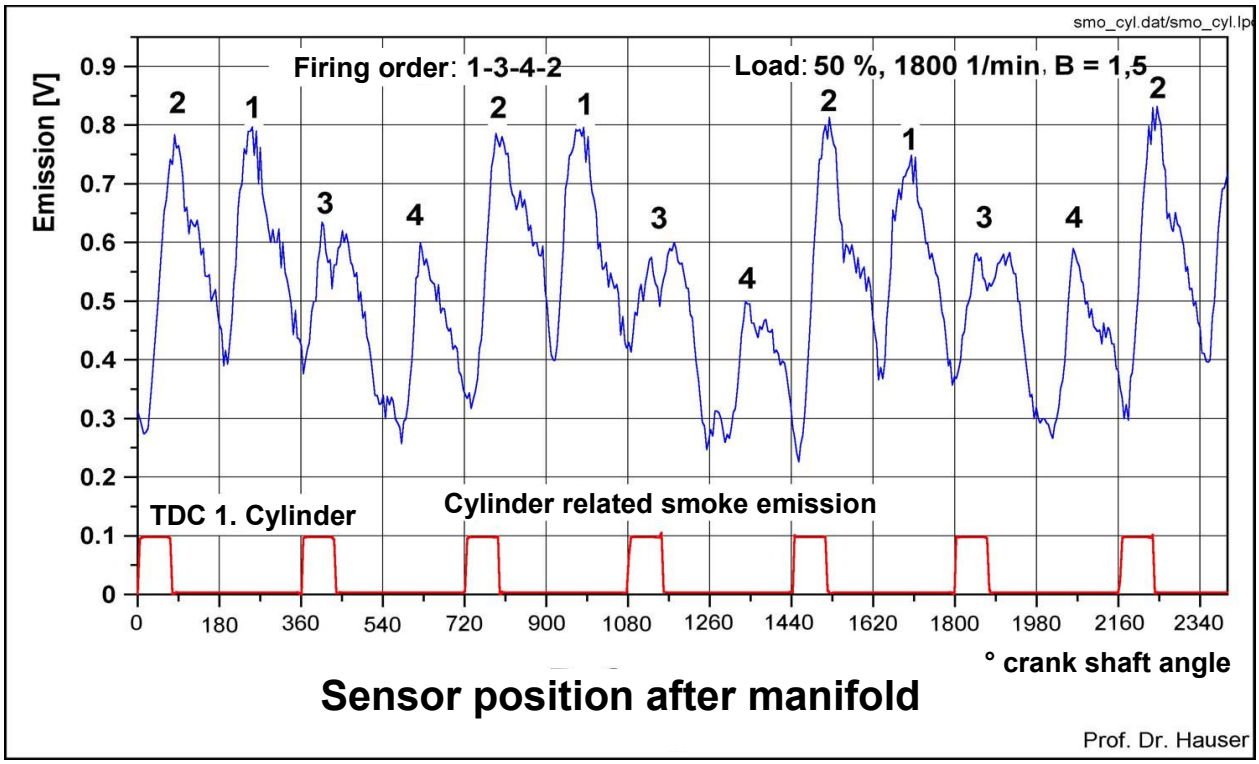
The result shows that a trap fault of 2 % can be detected even at no-load operation of the engine under OBD conditions.

This soot charging sensor was modified and build into a stand-alone measuring instrument for particle trap inspections operating at the standards.

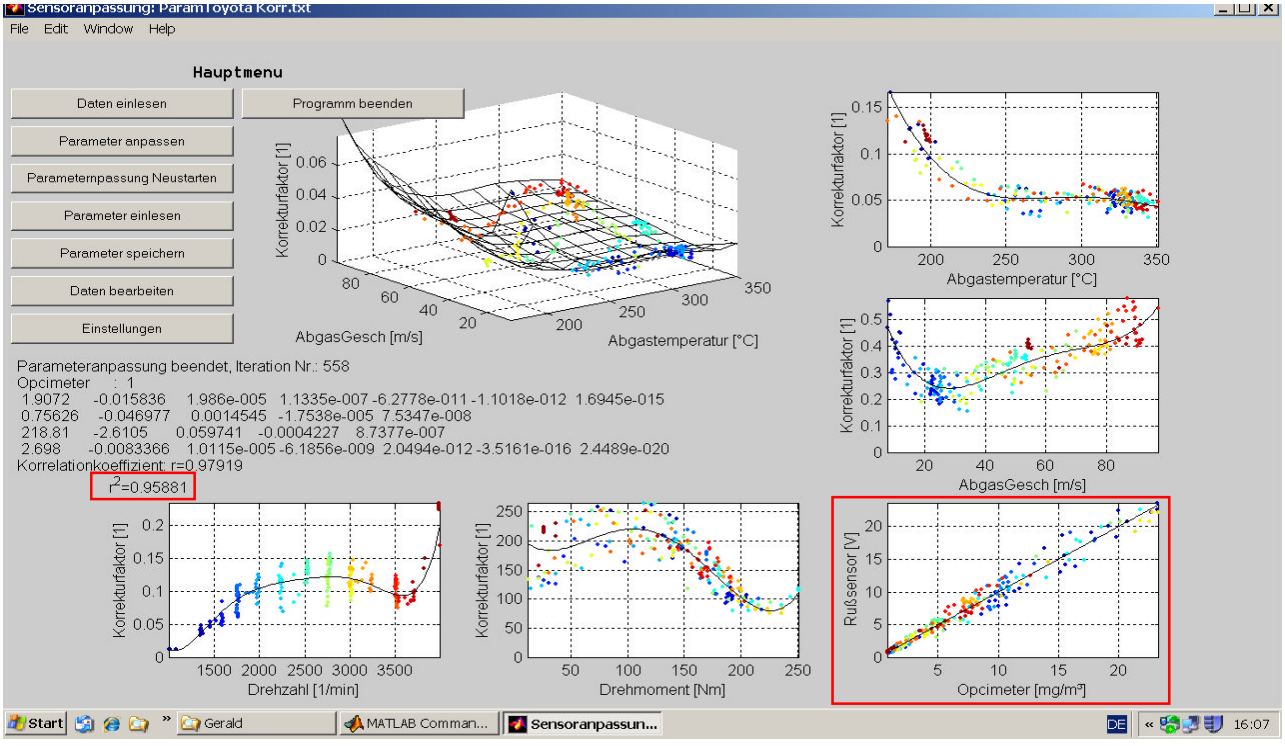




Further applications of the soot charging sensor for test bench investigations of the quality of diesel combustion processes are shown in next diagram.



It must be mentioned that, without knowing the exhaust gas speed, no calibrated measurement is possible. Therefore a software was designed to adapt these results on-line to a stationary operating soot measuring instrument. After this stationary procedure high speed soot measurements with a rise time of 10 [ms] can be achieved.



Chosen parameters which have influence on the quality of the soot particles are measured across the complete engine map. In this case engine speed, exhaust gas temperature, torque and the exhaust gas speed are chosen. Instead of torque and exhaust gas speed

the fuel consumption and the intake air mass could be used alternatively. The result consists of e.g. 4 exponential equations which will be implemented into the measuring software for the on-line operation at the test bed.

Conclusion

- The soot charging sensor in OBD operation measures continuously at high sensitivity down to 10 µg/m³ at 4 s rise time.

- No cross sensitivities against CO, CO2, H2O, HC, NOx, NO2

- Correlation to other measuring technologies:
- R^2 = 0,97 for particle mass, R^2 = 0,95 for SFN, R^2 = 0,93 for opacity

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