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Determination of the soot mass by conductometric soot sensors

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Abstract

Soot sensors are required for on-board diagnostics (OBD) of automotive diesel particulate filters (DPF) to detect filter failures. If installed upstream of a DPF, the “engine-out” soot emissions can be determined by conductometric soot sensors. For that purpose, conductometric soot sensors were characterized in a diesel engine under varying operation conditions. Sensor data and soot analytics (SMPS) agree well. However, the orientation of the sensor electrodes with respect to the exhaust flow direction significantly affects the sensor signal.

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Keywords: On-board diagnostics (OBD), Diesel particulate filter (DPF), Soot sensor

1. Motivation

Stringent emission legislations require the use of diesel particulate filters (DPF) in the exhaust gas aftertreatment of lean-burn diesel vehicles [1]. For on-board diagnostics (OBD) purposes, a soot sensor is mounted downstream of the filter. Typically, these sensors are conductometric devices [2-6]. When a DPF failure occurs, i.e. when soot passes through the filter element, the electrically conductive soot particles get deposited on the sensor surface where they percolate between the sensor electrodes and lead to a measurable current between them. The present contribution investigates whether this principle could also give a measure of the soot mass when the sensor device is installed upstream of the DPF.

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2. Experimental

Simple soot sensors were built up on insulating alumina substrates. Interdigitated Pt-electrodes (IDE, line = space = 100 µm) were screen-printed on the top side, where the soot particles should be deposited. Heater structures for active regeneration were also screen-printed on the reverse side of the substrate. After wiring, the sensor elements were housed in a stainless steel tube and were mounted in the exhaust pipe of a 2.1l (2143 cm³) diesel engine downstream of an oxidation catalyst (Fig 1).

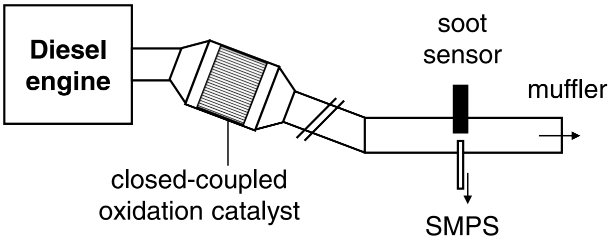

Fig. 1. (a) Dynamometer test setup and soot sensor mounting position.

The sensor signal was achieved discontinuously. By applying 20 V (dc) on the IDE, a current *I* appears (Fig. 2) after a characteristic "percolation time", which is the threshold when first soot paths from one electrode to the other form due to electrophoretic deposition of electrically conducting soot particles. Since this is a typical accumulating (or integrating) type sensor, the time derivative may be an appropriate signal to determine the actual concentration [7]. Therefore, the slope of the current (d*I*/d*t*) was evaluated for each cycle and was considered as the sensor signal. After a distinct current value, a new cycle was started by heating the sensor to 600 °C to remove the previously deposited soot. The regeneration temperature was adjusted by a heater controller. During soot collection, the heater (four-wire connection) was used as a temperature sensor.

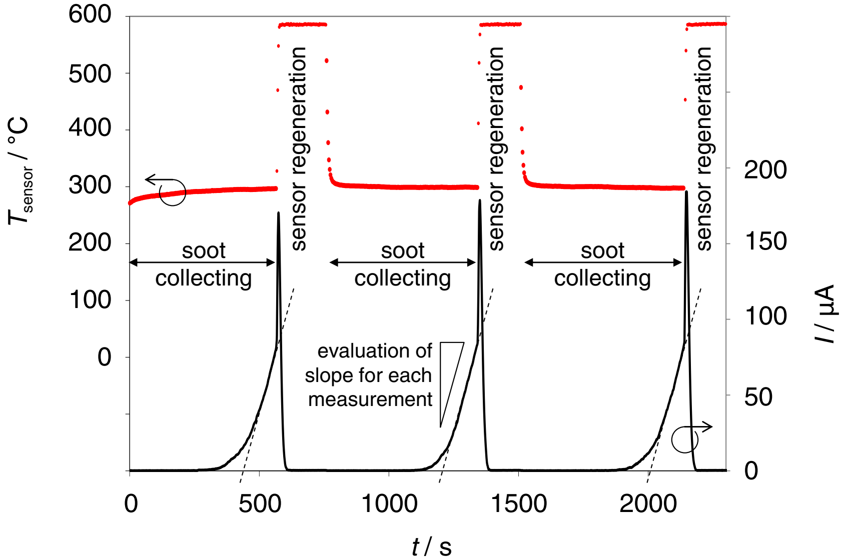

Fig. 2. Typical experiment (raw data, here at constant operation conditions: boost pressure = 1.25 bar, injection pressure = 660 bar, λ = 1.26). During soot collection, the current, *I*, increases constantly. Regeneration takes place by heating the sensor to 600 °C. Soot conductivity increases with temperature before soot is burned off. Evaluation of current derivative (slope d*I*/d*t*) is a measure for the amount of soot in the exhaust.