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ON-LINE/IN-LINE MEASUREMENTS OF PARTICLE EMISSIONS OF DIESEL ENGINES BY OPTICAL MULTI-WAVELENGTH TECHNIQUE

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Keywords

Particle emissions, optical on-line/in-line measurements, non interfering measurements

Abstract

A system for the on-line/in-line measurement of soot particle sizes and concentrations in the undiluted exhaust gas of diesel engines was developed and successfully tested. The unit uses the individual attenuations of three different laser wavelengths and is combined with an optical cell (white principle) with adjustable path lengths from 2.5 to 15 meters.

1 Introduction

Sharpened European and national regulations for the exhaust gas of diesel engines demand improved particle measurement systems for the periodic inspection and particle analysing tools for enhanced motor developments.

The importance of getting also a size information along with the concentration values has grown up with the up-coming discussion of the health effects of soot emissions.

The presented measurement system delivers both: Size and concentration information directly retrieved from the undiluted exhaust gas from vehicles on a chassis dynamometer and also from engines on motor test benches.

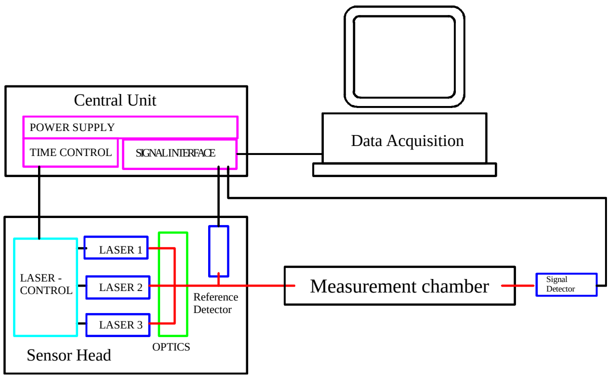

Fig 1: Schematic of the new sensor

2 Measurement unit

The sensor head (Fig. 1,2) contains three laser diodes of different wavelengths which are combined in one focussed beam. The spectral attenuation of the three wavelengths is captured at a single detector and the particle diameter and concentration is evaluated by the use of the Mie theory [1] and shown on-line with the speed of 1 Hz.

A commercially available optical long-path-cell (Fig. 3, white principle) was modified with a new developed purging and flushing system. This unit has a base path length of 62.5 cm, and allows an adjustment of the optical path length from 2.5 to 15 m by a mirror system.

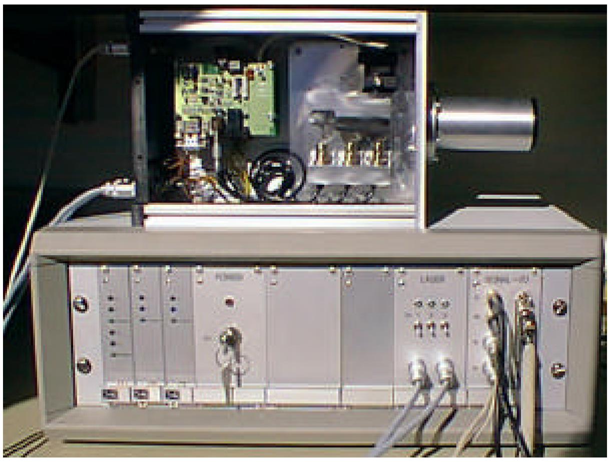

Fig. 2: Sensor head with supply and interface unit

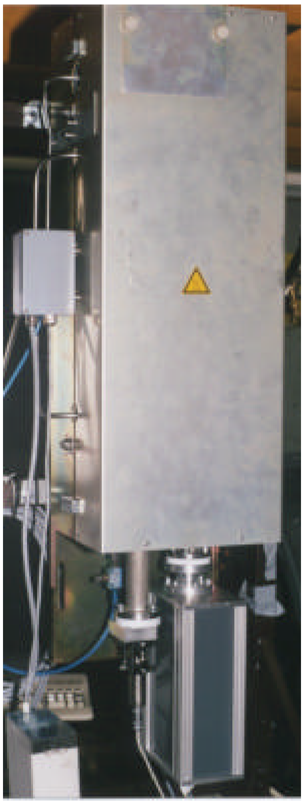

Fig 3: Sensor with optical

The measurement cell and the exhaust gas tubes are heated and thermo-controlled to avoid conflicts with deposition and interferences by condensation i.e. formation of water droplets.

Temperatures and pressures are recorded to allow the calculation of standard conditions.

The use of the long-path-cell enlarged the dynamic range of measurable concentrations compared to previous measurements within a long tube [2,3] so effectively, that also measurements at engines with filter aftertreatment systems are intended.

Fig. 3 shows the sensor, consisting of the signal detector and the transmitting unit adapted to the long-path-cell at the bottom side.

3 Results

The on-line graphs in Fig. 4 contains the whole aerosol information:

① Mean Diameter:
Volume concentration
Raw intensities of the three lasers
Theoretical field

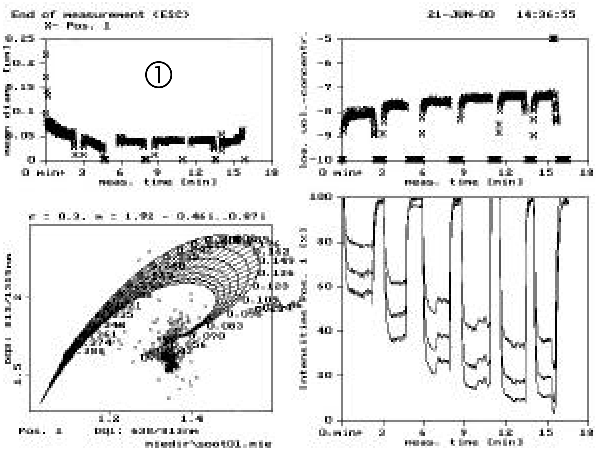

Fig. 4: On-line graph of the system

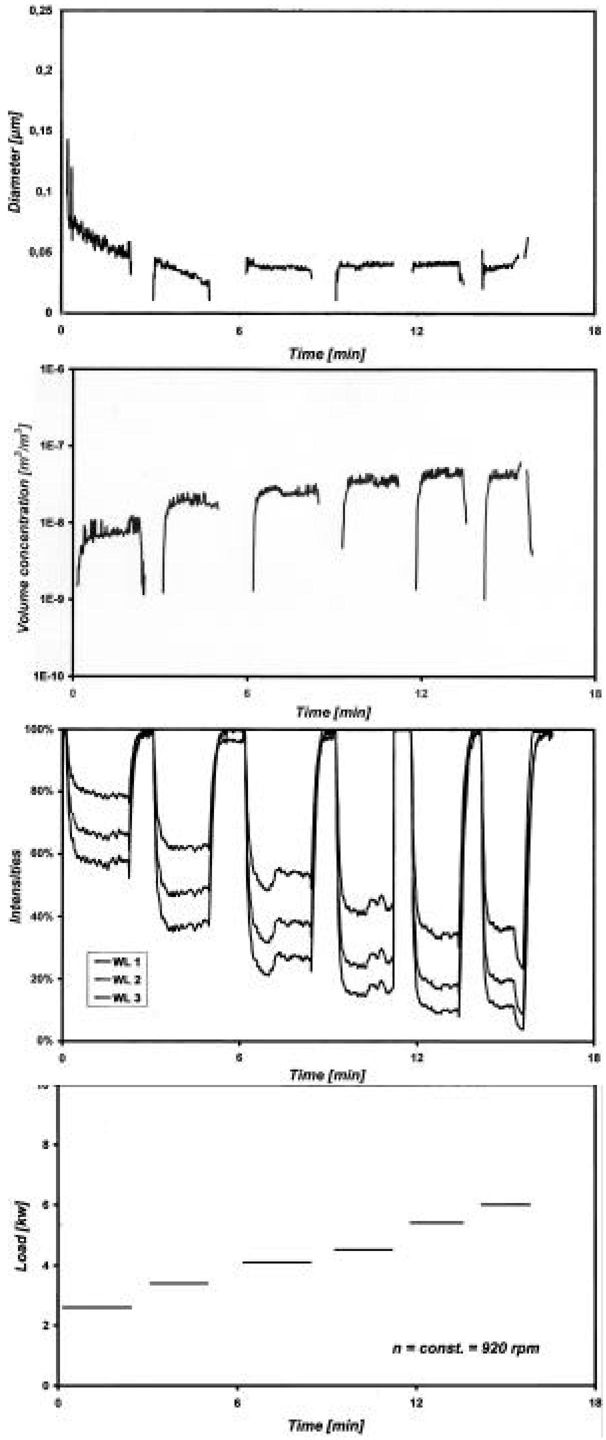

Fig. 5 a-d: Results of an AUD 1,9l TD on a chassis dynamometer

Fig. 5 shows the detailed results of this specific measurement. Different loads, starting with idle conditions, under constant speed of rotation are recorded for an AUDI 1,9l TD on a chassis dynamometer (Fig. 5d).

The graphs show clearly that the mean diameter of the emitted particles are well below 100 nm (Fig. 5a). The Mie calculations are based on the assumptions of a log-normal distribution and spherical particles. If chain like agglomerates are present in the aerosol, this optical system measures in good agreement with REM images the diameter of the spherical primary particles.

In some older engines, a correlation between engine´s load and emitted particle size was found. This correlation is not so clearly manifested in modern engines with direct injection or exhaust gas recirculation. Further investigations are under way.

As expected, the concentration (Fig. 5b) follows the engine´s load increase. The load was enlarged stepwise, interrupted by manually activated reference measurements.

Fig. 5c clearly demonstrates the different extinction characteristics of the individual wavelengths in the soot aerosol.

The on-line presentation of the measured values in the theoretical Mie field indicates the quality of the actual results (Fig. 4,). It was found, that a refractive index of n = 1.92 – 0,66i delivers best results for all diesel engines.

In earlier examinations the correlation of the used measurement principle (with this refractive index) to traditional gravimetric and opacity measurements was confirmed [4]. The experimentally found soot density of $\rho = 0.55\ g/cm^3$ is also approved by other literature [5].

4 Conclusion

The particle analyser based on the optical multi-wavelength extinction proved to be a most reliable tool to measure on-line and in-situ directly the undiluted particle emission of diesel engines. The two main aerosol parameters „mean diameter" and „volume concentration" are recorded in the on-line mode.

Advantages of the new measurement system are the use of undiluted exhaust gas and the fast adaptation to engine systems by a simple thermo-controlled hose. The on-line capability permits the measurement of either stationary or transient motor conditions.

A white cell is mandatory for modern diesel engines: An adjustable optical path length of up to 10 m allows the analysis in a sufficiently broad concentration range.

Further developments in extending the features to record representative gaseous species in the exhaust gas are in progress [6,7].

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