

Quantitative soot measurements in an HSDI Diesel engine

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Quantitative in-cylinder measurements of soot volume fraction in a 0.5 l single-cylinder HSDI Diesel engine based on the VOLVO D5 has been carried out using the laser-induced incandescence (LII) technique. Optical access to the combustion chamber was obtained by a fused silica ring inserted as the upper 25 mm of the cylinder liner, as well as by a piston assembly of Bowditch type. The aim of maintaining a realistic chamber geometry was realized by the design of the fused silica piston head which very closely resembles that of the production engine.

The 1064 nm beam from a Nd:YAG laser was formed into a thin sheet and aligned into the combustion chamber. Two configurations were used. Configuration 1, in which a slightly tilted horizontal laser sheet entered the cylinder through the fused silica ring and signal was detected through the piston (Fig. 1a), and configuration 2, in which the laser sheet entered via the piston, and the signal was detected from the side via the liner (Fig. 1b).

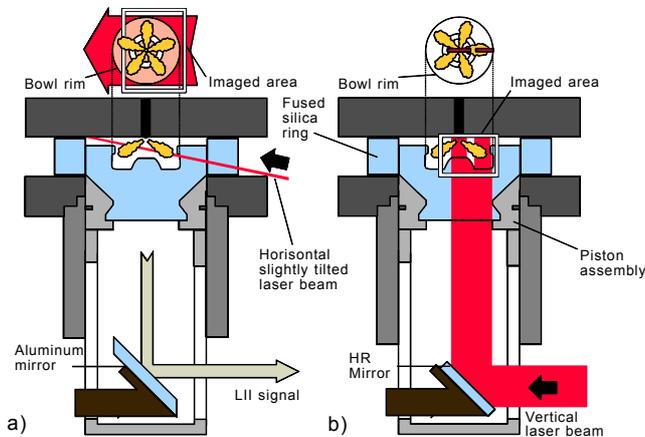


Fig. 1. The optical configurations. a) Imaging through the piston bowl (config. 1), and b) imaging through the ring (config. 2).

A gated ICCD camera with a prompt 30 ns gate was used to detect the LII signal in a broadband detection at wavelengths shorter than 450 nm. For quantitative data the measurements were calibrated using a well-characterized atmospheric flat flame burner. The difference in pressure, temperature and soot properties between the reference burner and the cylinder may give rise to systematic errors in the quantification. These issues are discussed and theoretically investigated using a heat and mass transfer model for LII. In Fig. 2 examples of probability density distributions obtained using the two configurations are presented. The contour levels indicate the probability of obtaining a soot volume fraction exceeding a given ppm.

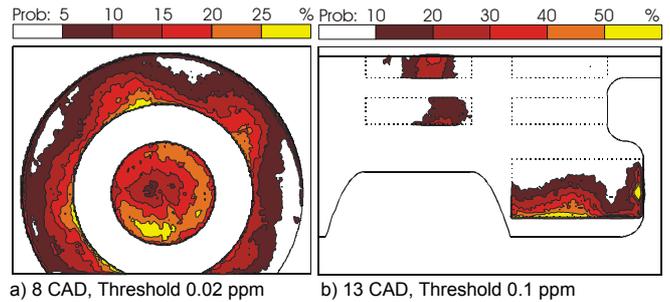


Fig. 2. Examples of probability density distributions of absolute soot volume fraction levels measured using the two configurations.

Two different operating condition schemes were investigated. In the first, which was carried out using configuration 1, the soot production for different amounts of EGR was investigated. The EGR level, defined as the engine exhaust CO₂ level divided by the intake CO₂ level, was varied on the right side of the so called smoke-bump, i.e. where an increasing EGR level results in lower engine-out soot levels. This behavior is consistent with the cycle-averaged soot volume fraction levels shown in Fig. 3 together with the corresponding heat release rates.

In the second part of the investigation, which was carried out using configuration 2, the injection event was divided into one pilot injection and one main injection at a constant EGR ratio of 60%. The CAD position of the pilot injection was varied, while keeping the position of the main injection constant. Early pilot injection timings resulted in excessive fouling of the optical parts, thus limiting the accuracy of quantitative measurements. Still, the flow pattern of the soot within the cylinder is presented and discussed.

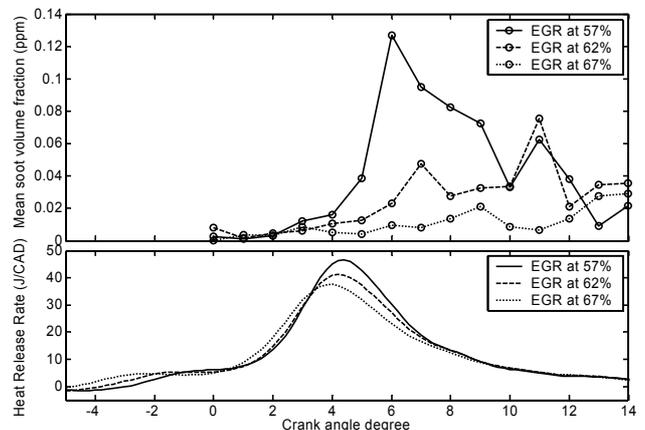


Fig. 3. Average soot volume fractions and heat release rates for the three different levels of EGR.