Time-resolved laser-induced incandescence applied to in-cylinder Diesel particle sizing

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Laser-induced incandescence with time-resolved detection (TR-LII) in two frequency channels was established and applied to the combustion chamber of a single-cylinder two-stroke Diesel engine. It was possible to determine the mean particle diameter and the geometric standard deviation of an assumed lognormal size distribution for the in-cylinder particles as a function of the crank angle. The measured sizes were in good agreement with the primary particle sizes in the exhaust gas determined by TEM-analysis.

Introduction

For any further reduction of the particlulate emissions of Diesel engines a better understanding of the processes of particle formation and oxidation inside the combustion chamber would be helpful. For that purpose a particle-measuring method yielding instantaneous information about the particle size distribution at different stages of the combustion cycle would be worthwhile.

Time-Resolved Laser-induced incandescence (TR-LII) has become a common method for in-situ particle size measurements. In the present study a two-color version of TR-LII [1, 2] was established and applied to a Diesel engine. The objective was to determine the particle count median diameter *CMD* and geometric standard deviation σ_g of an assumed lognormal size distribution of the particles as a function of the crank angle.

Experiments

The experiments were performed on a single-cylinder, two-stroke Diesel engine with a displacement volume of 250 cm^3. A custom designed cylinder head provides the required optical access. The engine was motored by an electrical asynchronous motor at a constant speed of 1500 min^{-1}. For the TR-LII measurements, the engine was fired for some individual cycles only. All experiments were performed at an injection crank angle of 23° CA BTDC and an air/fuel equivalence ratio of $\phi = 0.26$. The particles were heated by an Nd:YAG laser at 1064 nm with a laser fluence of 0.10 J/cm^2.

Finally, a thermophoretic particle sampler was located in the exhaust gas manifold to get particle probes for further analysis by transmission electron microscopy (TEM).

Results

A series of normalized particle emission signals during cooling obtained at six different crank angles is shown in Fig. 1. Particle cooling strongly depends on the engine crank angle and becomes longer with increasing crank angle.

The signals of Fig. 1 and others were evaluated in terms of particle size by fitting lognormal distribution functions to the measured curves under the variation of *CMD* and σ_g. The results are shown in

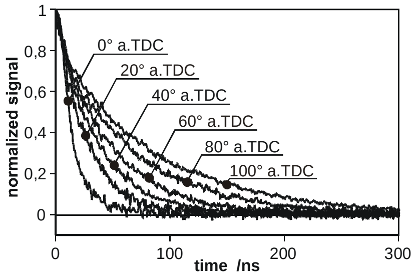

Fig. 1: Normalized TR-LII signals at six crank angles.

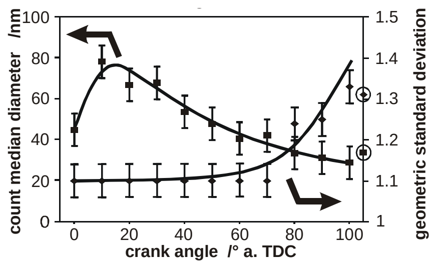

Fig. 2: CMD and σ_g evaluated from the signals in Fig. 1.

Fig. 2. *CMD* is in the range of 30 to 75 nm, increases up to a crank angle of about 10° CA and decreases again towards a value of about 30 nm at 100°CA after TDC. This behavior can be explained by particle formation and subsequent particle oxidation. σ_g is constant at a value of 1.1 up to a crank angle of 70°CA and then increases towards about 1.32. The two circled values of *CMD* and σ_g, which are shown at the right edge of the diagram, are results of the TEM analysis of the exhaust gas primary particles. The agreement between the TR-LII measured sizes at 100°CA after TDC and the TEM determined primary particle sizes in the exhaust gas is quite good.

References

1 B.F. Kock, C. Kayan, J. Knipping, H.R. Orthner, P. Roth, Proc. Combust. Inst. 30, 1689 (2005).
2 B.F. Kock, P. Roth, Two-Color TR-LII Applied to In-Cylinder Diesel Particle Sizing, Proc. Europ. Combust. Meeting, Orléans, France, Oct. 25-28, 2003.

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