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Investigation of In-Cylinder Soot Formation and Oxidation by Means of Two-Dimensional Laser-Induced Incandescence (LII)

by

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ABSTRACT

Increasing requirements on the environmental acceptability of internal combustion engines led to strong efforts to meet the continuously getting stricter emission regulations. New concepts of combustion and injection have been developed together with appropriate techniques of exhaust gas aftertreatment. For diesel engines especially modern high pressure injection systems, such as the application of distributor pump and common rail have been applied successfully. However, internal mixture formation, ignition and combustion for this new systems are not completely understood so far. Optical measurement techniques offer the possibility of the in-situ investigation of the combustion process. An appropriate method for soot measurements, which is without source of interference also applicable to technical systems, is given by laser-induced incandescence (LII). The principle of this technique is to heat up the soot particles by a highly energetic laser pulse to temperatures well above ambient temperature and to detect the resulting thermal radiation. For appropriate experimental conditions, the signal can be shown to be proportional to the soot mass concentration within the detection volume.

In this work, basic features of the technique are discussed in detail, especially with respect to the application within diesel engines. One aspect of particular interest is the range of detection wavelengths, which has to ensure a mass proportional signal of sufficient magnitude, but also the suppression of flame luminosity and especially elastic scattering of walls, droplets and dust. Another important point to consider is attenuation of both the incident beam and the signal due to light absorption, scattering and blinding of the optical access. Measures to minimize these influences are discussed.

The soot formation and oxidation process inside the combustion chamber of a DI diesel engine was investigated by means of two-dimensional LII. For this purpose, a thin light sheet was introduced into the piston bowl of an optically accessible diesel engine, which is very close to the serial standard and driven with standard diesel fuel. The detection was performed perpendicularly to the incident beam through a transparent piston window and a mirror which was mounted inside the slit of the elongated piston. First results of a common rail injection system are presented for a mini-sac-hole nozzle. Sequences of the LII signal and flame luminosity were measured in a time interval from before top-death-center (TDC) to about 30 degrees crank angle after TDC. The comparison to investigations of natural flame luminosity, which can be detected simultaneously, is shown to give valuable additional information. It is, e.g., possible to detect a LII signal without the simultaneous occurrence of flame luminosity, which can be interpreted as originating from soot, which will not be further oxidized due to the end of the diffusion flame. This portion will be emitted later on within the exhaust stroke. Generally, the flame does not cover the complete piston bowl for the operation conditions investigated in this study.