Soot volume fractions and primary particle size estimations by means of simultaneous time-resolved and 2D laser-induced incandescence

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The challenge of the present study is to characterize the soot formation "as quantitatively as possible". Due to its good spatial and temporal resolution, the Laser-Induced Incandescence (LII) technique seemed to us to be the most suitable one to quantify the soot. A simultaneous application of two-color time-resolved LII and 2D LII was our particular approach to have in the same time bi-dimensional information regarding soot concentration and punctual information on particle mean size. A pilot study was conducted in order to quantify the soot volume fractions and particle size in an atmospheric pressure laminar flame by means of this simultaneous technique. Soot concentration and size estimations have been eventually performed inside the combustion chamber of a Diesel engine.

Introduction

The combustion characteristic to Diesel engines is a source of pollutant emissions, the soot being one of the most important representatives. Even that the latest technologies e.g. high-pressure direct injection have a direct contribution to the Diesel soot emissions reduction, further research should be done to meet the limits imposed by the pollution limits in order to preserve the air quality. Before finding solutions to reduce the pollutant emissions, it is necessary to understand their formation and, if possible, to perform quantitative *in-situ* measurements.

Laser-Induced Incandescence Application

One of the techniques that allow quantifying the soot non-intrusively and in situ is Laser-Induced Incandescence (LII), this technique being in our opinion the most suitable to apply for soot volume fraction and the primary particle mean diameters estimations inside the combustion chamber. It consists basically in heating the particles by means of a pulsed laser beam up to the vaporization temperature and to record the incandescence signal that has a diameter-dependent evolution versus time and scales with the soot amount in the measurement volume.

One of this technique's most recent approaches is based on estimating the soot heated temperature by means of the two-color pyrometry. It is based on the recording LII signal at two wavelengths. The soot volume fraction is then calculated with a Planck-type formula [1]. The individual time-resolved (TR) signals may be used to estimate soot particle sizes trough energety transfer models.

A combination of the two-color TR-LII technique and 2D LII imaging allows us to make estimations regarding the soot concentration inside the combustion chamber of an optically accessible Diesel engine. Our strategy consists in recording a time-resolved signal filtered at two different wavelengths simultaneously with a LII image. The two-color time-resolved signals recorded for a small measurement volume allow estimating the soot laser-heated temperature and then the soot volume fraction for that "punctual" location. The ratio between the so-calculated soot volume fraction and the average image intensity corresponding to the small measurement volume is actually the factor that we use to express the intensity units of the image in soot volume fraction units.

The experimental set-up consists of a pulsed Nd:YAG laser at 1064 nm, the reactive media (optically accessible Diesel engine or atmospheric pressure flame) and for signal detection and recording an ICCD camera and two photomultipliers tubes connected at a rapid acquisition system.

Soot volume fractions and soot sizes in the atmospheric pressure flame were first estimated with the two-color LII technique in several points of the flame. Our simultaneous application of the LII technique in the flame proved a good agreement with the two-color pyrometry results. Soot size estimation in atmospheric conditions has been done through the LII model described in the reference [2]. Thermophoretic sampling results prove that the estimated mean diameter assuming monodisperse soot size is close to the count mean diameter of the lognormally-distributed sampled soot size. Soot volume fractions and sizes were eventually estimated inside the combustion chamber of a Diesel engine. The soot size was estimated through the high pressure model described in reference [3]. EGR effects on soot formation were also investigated.

References

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