Micro-macro Characterisation of Sprays for Combustion Analysis Using Alternative Diesel Fuels

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Introduction.

Due to the depletion of the fossil fuels on the one hand and the need for climate protection on the other the further development of the internal combustion engines is absolutely necessary in order to reduce fuel consumption and CO_2 emissions. At the same time the application of new fuels, in particular the bio fuels of the second generation, gains in importance. Therefore the diversification of those alternative fuels and in particular the influence of their properties on the spray on the micro and macro scale in matters of the air-fuel mixing process is an important aspect of the future combustion process development, in which numerical simulations demanding experimentally based models are being employed due to the lack of self-consistent ones.

The phenomena occurring during the spray formation process can be described by the distribution parameters of particle systems and particularly the micro-macro-interactions of the fuel droplets among each other, with the surrounding air and the piston walls, their evaporation and the following combustion.

Problem Definition

Even though alternative fuels have resemblance with the diesel fuel, they possess slightly different physical and chemical properties, which could lead to diverse spray development, fuel-air mixture formation and other combustion and exhaust emissions characteristics.

Objectives

Those differences evoke the need to closely examine the spray propagation of the chosen alternative fuels, its dependence on the in-cylinder flow and their atomization characteristics. In addition the spray parameters are to be correlated with their combustion behaviour.

Cooperation

Dipl. Ing. S. Baer, member of GK
Dipl. Ing. F. Schulz, associated member of GK
Prof. Rottengruber, Institute of Mobile Systems
Prof. Hadler, Institute of Automotive Expertise
Volkswagen AG

Pressure chamber for micro-macro spray characterisation

In order to investigate the microscopic spray characteristics of the fuels of interest, phase Doppler anemometry was employed on a high pressure vessel, see Figure 1. That way the atomisation properties of the different fuels can be analysed at engine like conditions by means of the droplet diameter and velocity.

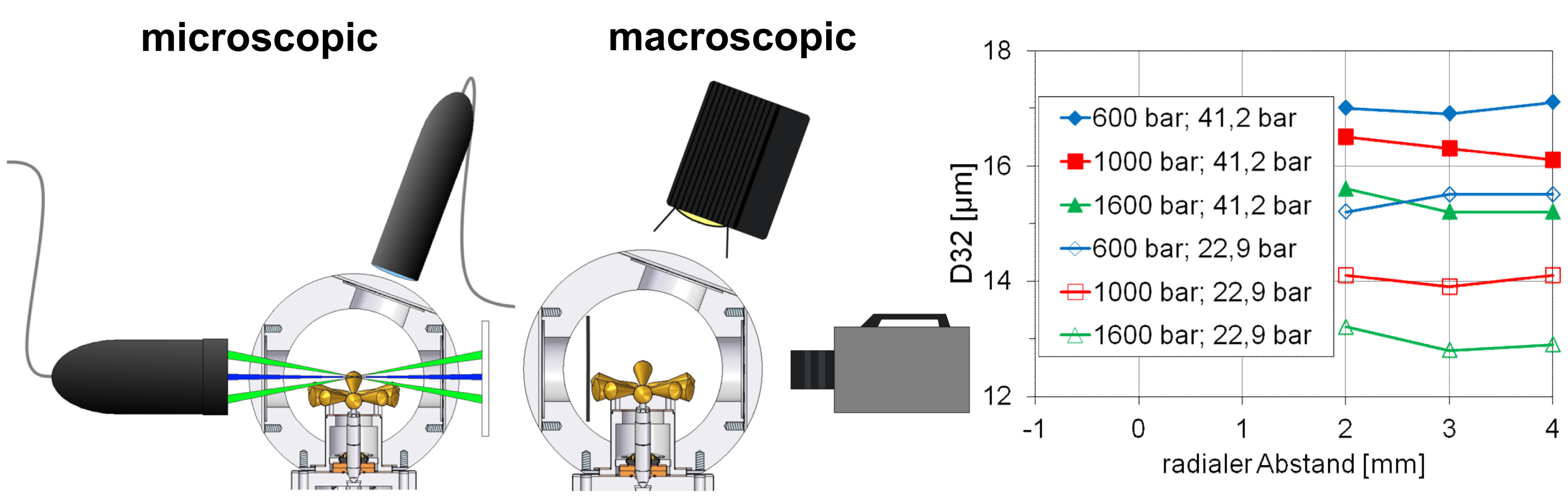
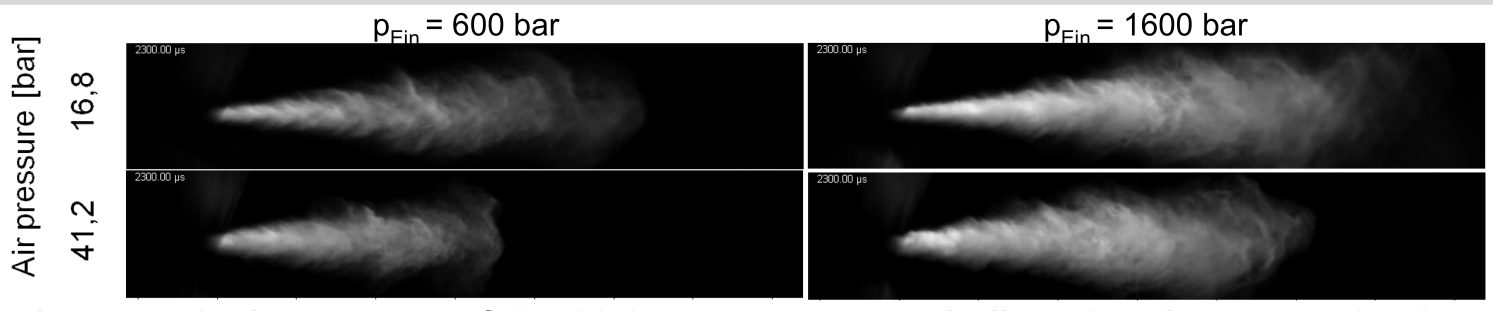


Figure 1. Test-rig for Phase Doppler Anemometry (left) and high speed visualisation (center) and sauter diameter at different injection and air pressures



The large optical accesses of the high pressure vessel allow the close examination of the single spray providing more detailed information about spray geometry, see Figure 1.

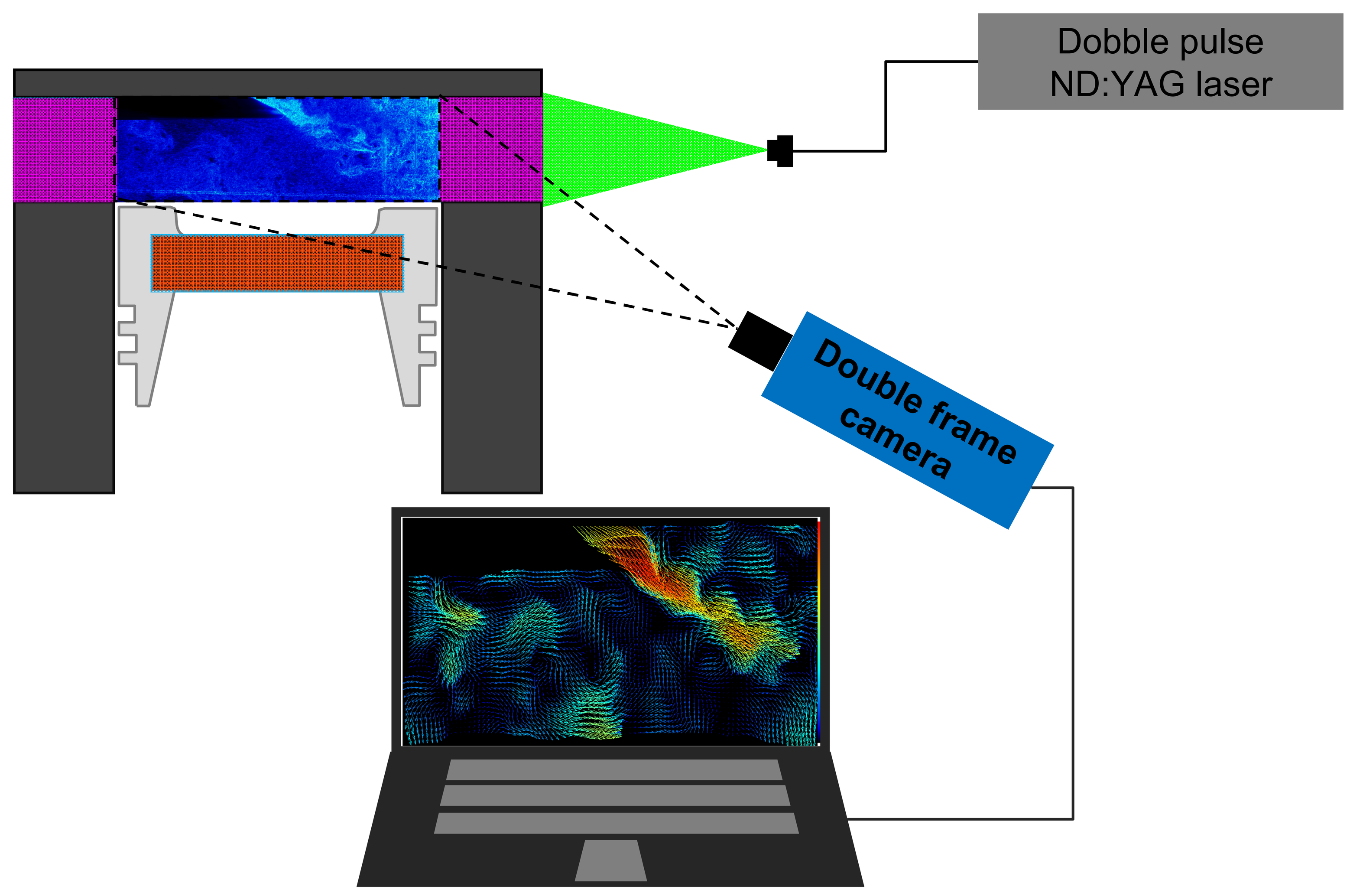


Figure 4. Experimental setup for Particle Image Velocimetry (PIV)

Spray investigations in a combustion engine

The single-cylinder optically accessible engine was used to investigate the spray propagation of the fuels in question under real engine conditions using the Mie-scattering technique, see Figure 2. Recorded images were processed in Matlab to extract the spray cones and to enable the estimation of the macroscopic spray parameters: penetration, angle, volume and tip velocity.

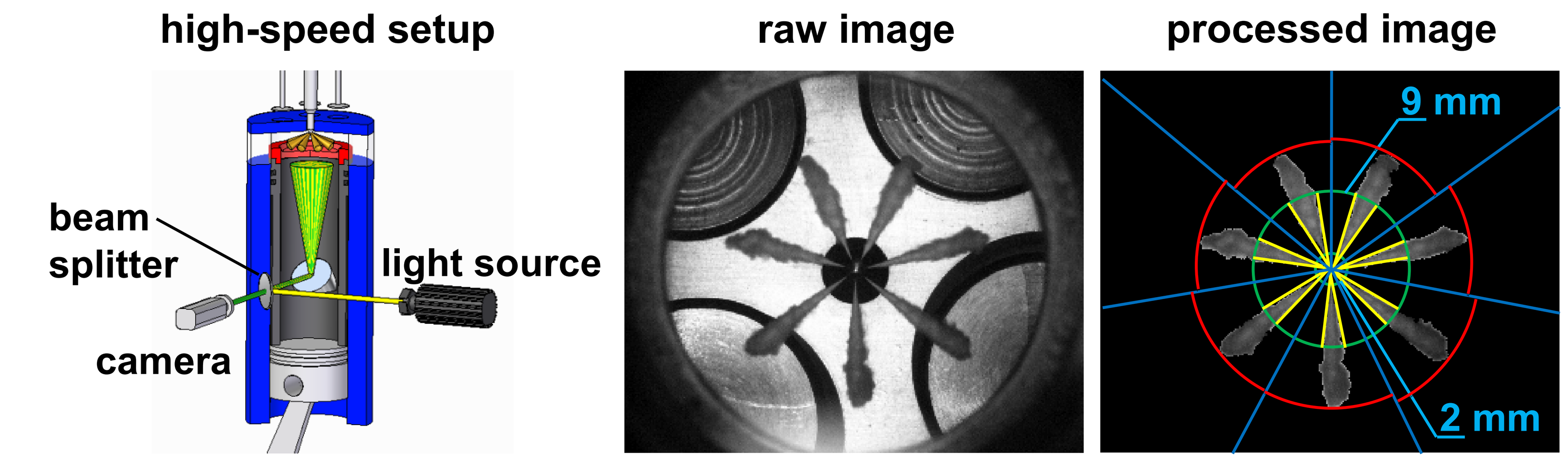


Figure 2. Experimental setup for high-speed and data processing

To aid the evaluation of the fuels their combustion behaviour was analysed and in particular the soot formation by detecting the flame natural luminance. The thermal radiation from the incandescent soot particles was detected at 700 nm considering the following problems, see Figure 3:

- soot formation temperatures and therewith the temperature dependence of the soot particle radiation
- emissions from other radicals: OH, CH, C_2, HCO, NH, NH_2, H_2O, CO_2, N_2O a.o
- spectral irradiance of black bodies
- camera sensitivity

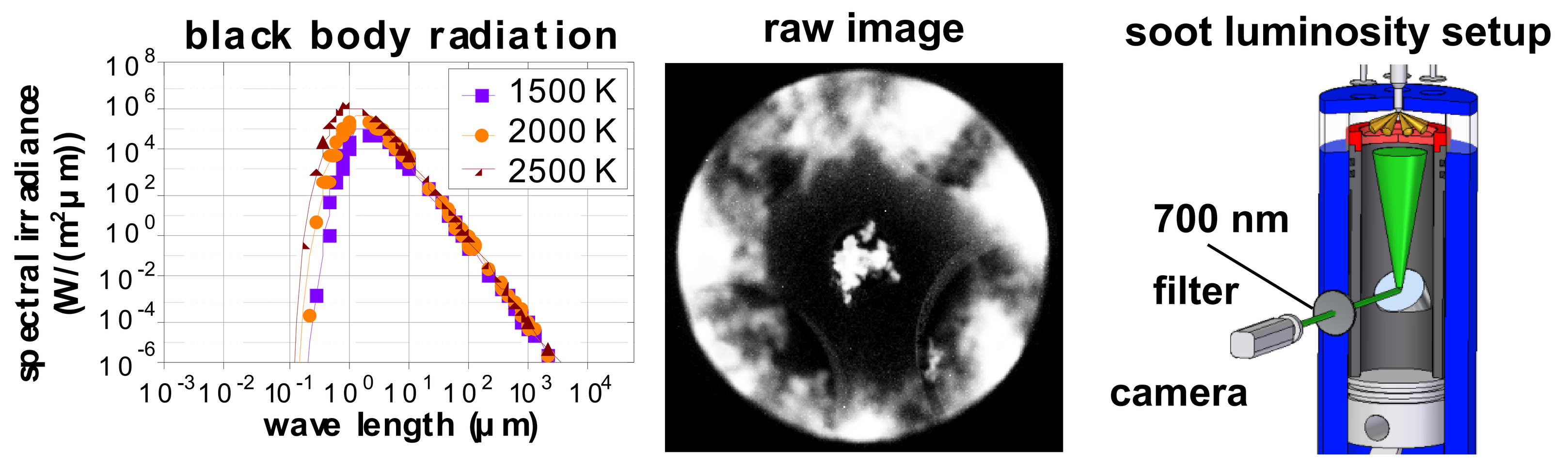


Figure 3. Spectral irradiance of black bodies, raw image and setup for soot luminosity

The engine performance and emissions are greatly influenced by the in-cylinder air motion. Moreover an optimized in-cylinder flow can enhance air-fuel mixing and lead to lower exhaust emissions. In addition the turbulent flow in the cylinder exhibits large- and small-scale cyclic variations, which can also have a pronounced influence on the combustion process. Therefore Particle Image Velocimetry (PIV) was employed on an optically accessible diesel engine to analyse the in-cylinder flow during the intake and compression phases, see Figure 4. This technique was also used to investigate the spray development and in particular the effect of the swirl on the spray.

Results and Discussion

An increase of the sauter diameter at higher surrounding air pressures could be observed.
During the PIV investigations at the single cylinder engine an influence of the swirl motion on the spray propagation at different engine speeds could be observed.
The low-viscous fuels gas to liquid (GTL) and hydrated vegetable oil (HVO) showed overall marginally wider spray angle and a higher spray front deceleration rate in comparison to rapeseed methyl ester (RME) due to their lower density and viscosity.
The fuels with higher cetane number (GTL and HVO) showed the strongest intensity of the soot particle incandescence.

Conclusions

Although the two fuels possess quite similar macroscopic spray characteristics, their combustion behaviour still has differences. Based on those preliminary investigations, it can be concluded that further work is needed to diversify the chosen alternative fuels.

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