Characterization of Wall Film Formation from Impinging Diesel Fuel Sprays using LIF

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Abstract

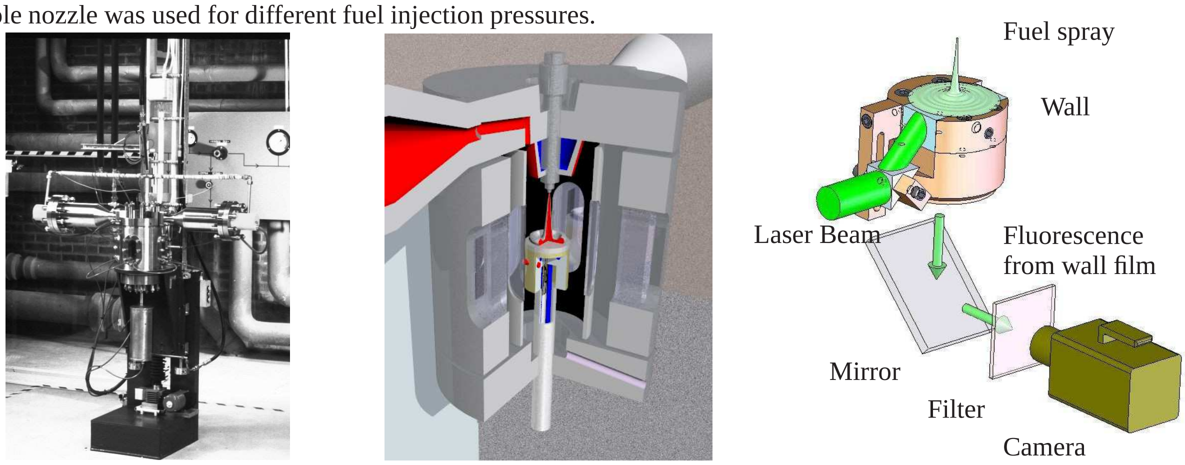
This work presents a study about Diesel fuel wall films made in a high pressure/high temperature spray rig with the purpose to characterize wall film formation at different injection conditions and to investigate the applicability of different optical techniques. Sprays are impinging on a quartz surface and the formed fuel film are illuminated by laser light through the quartz and the fluorescence is imaged from below.

Introduction

Problems related to fuel wall films in direct injected engines are of high priority when it comes to for example influence on engine-out emissions. Several studies about wall films have been conducted in the past, but nevertheless, there is not yet a real basis of knowledge in the field. Numerical simulations and experimental studies of spray/wall interaction have been done at Chalmers [1] and it have been found that a method for measuring the fuel wall film of impinging sprays is needed for validation. One promising method was presented by Alonso et. al [2] in 2008. They showed that laser induced fluorescence (LIF) is successful for quantitative 3-dimensional measurements of transient liquid fuel films. This can be seen as the motivation for this work where the objectives are to apply an optical method and create data for implementation and validation of computational models.

Experimental setup

For this experiment a new wall has been designed to be used in the high pressure/high temperature (HP/HT) spray chamber at Chalmers, Fig. 1. The wall allows the two optical set-ups of the LIF-technique, which relies on the idea that, upon excitation by laser light, the intensity of the fluorescent signal from a tracer in the fuel is proportional to the film thickness. Used in the first set-up an Ar-ion continuous laser together with a high speed camera were used, and for the second one a Nd:Yag pulsed laser together with an intensified CCD camera were used. The tested fuel was a commercial Diesel fuel, Swedish Environmental Class 1, with addition of a chemical tracer to increase the fluorescence. Several parameters, such as air temperature and air pressure, were chosen to achieve both evaporating and non-evaporating conditions. A standard common rail system together with a single-hole nozzle was used for different fuel injection pressures.



(a) Photo of the spray rig with the spray chamber located in the middle together with air heaters and pipes

(b) Sketch of the spray chamber with a four-window configuration demonstrating the height adjustable wall

(c) Sketch of the optical setup with a mirror, a high-pass filter, and a high speed camera to record the fluorescence from the wall film

Figure 1. Chalmers' high pressure/high temperature spray rig

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Previous work by Lindgren et al. [3], Kull et al. [4], and Hoon et al. [5], used a LIF technique to visualize fuel films on quartz surfaces and showed that it is possible to have total internal reflection using a certain incident angle. However, the light can propagate from the quartz into the fuel due to a similar refractive index. There is only a small change in the path of light when it propagates between media with similar refractive index. Total internal reflection between the fuel-air interface is needed in order to illuminate the fuel but not airborne drops.

Results and Conclusions

Figure 2 shows a sequence of the first injection of the multiple pulse captured with the high speed camera. The resolution of the pictures is 128x64 pixels and each image is taken every 0.3 ms starting at t=1 ms after the injection trigger. Fuel remaining from previous injection appears in the first image, then the fuel impinges the wall at t=1.3 ms. The film reaches each maximum thickness at a point under the nozzle, t=2.2 ms, and after that it starts to decrease to the time when the second injection reach the wall.

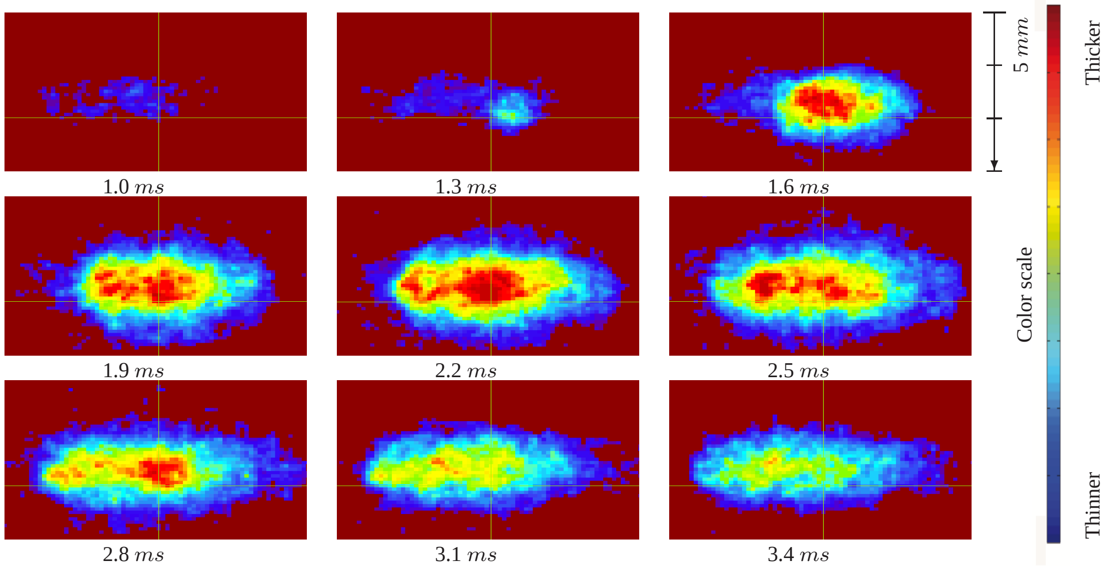

Figure 2. Fuel film spreading at an injection pressure of 1000 bar, an air temperature of 150 °C and a distance wall-nozzle of 60 mm.

Some conclusions about fuel wall film formation that can be stated from this work are: Firstly, the higher air temperature and air pressure the thinner film and therefore, the less ability to form a fuel film. Secondly, when increasing the fuel pressure the wetted area and the film thickness decreases. Same effect is noticed when reducing the surface to nozzle distance. Both pulsed and continuous lasers were compared and basically, the continuous one is suitable to record a complete sequence of one injection during time and the pulsed laser approach gives more detailed information in several instants of different injections.

Acknowledgement

Financial support from the Swedish Energy Agency and the Combustion Engine Research Centre (CERC) at Chalmers is gratefully acknowledged.

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