In Application

Hydrogen Imaging in Automotive Powertrains

FluidMaster BOS system

Introduction

Hydrogen (H_2) as an energy source for automotive propulsion is becoming increasingly important to reach future sustainability goals. Not only for powering fuel cells but also for H_2 fueled internal combustion engines (ICE). Therefore, it is obvious to combine the advantages of H_2 as fuel with advanced ICE technology.

However, it is known that the behavior of gaseous fuels is inherently different to liquid fuels (e.g. gasoline) when injected or blown into the engines either through direct injection (DI) or port fuel injection (PFI). Knowing the spatial distribution of H_2 during the mixture formation process is therefore essential for valve designing, optimizing combustion processes and validating numerical simulations.

Typical methods for spray imaging of liquid fuels, for example the Mie scattering or shadow technique, are not suitable for gaseous fuels. Standard laser-based techniques, like PIV or LIF, depend on the need of tracer material to be seeded into the flow and require a high technical effort.

The Karlsruhe "Institut für Kolbenmaschinen" (IFKM) applied the straight forward **Background Oriented Schlieren** (**BOS**) technique at a pressure chamber to visualize the time-resolved hydrogen distribution using a commercial gas injector (Bosch NGI2).

Figure 1: Experimental setup with high-speed camera and pressure chamber

Background Oriented Schlieren technique

BOS is a digital Schlieren technique and works on detecting changes in the refractive index of media. Thus, making it possible to effectively visualize H_2 in contrast to the rest of the engine's charge. The main advantage of BOS is the simplicity of the implementation. All that is required are a digital camera and the BOS pattern printed on a screen. Figure 1 shows this principal setup for characterizing gas injection valves. Additional illumination of the pattern helps to increase the contrast of the recorded images, especially for time- resolved high-speed imaging. The processing of the recorded images to visualize the H_2 is carried out by the LaVision DaVis 10 BOS software package.

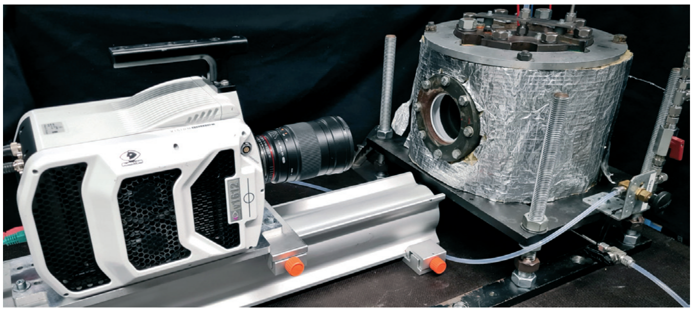

Figure 2: Photo of experimental setup

Experimental setup

The experimental setup at the IFKM is shown in Figure. 2. A high-speed camera is mounted in front of the heated pressure chamber with optical access at the front and rear. The gas injector is mounted at the top of the chamber. The illuminated BOS-pattern (not visible) is placed at the rear side of the chamber.

For simulating back pressure conditions the cell was pressurized with nitrogen (N_2). Single injection conditions were recorded with a frame rate of 10 kHz. A variation of the hydrogen injection pressure showed a penetration depth change with higher pressure at the same time. This evolution is shown in single images from the high-speed movies at the same time interval in Figure 3.

LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306

Hydrogen Imaging in Automotive Powertrains

FluidMaster BOS system

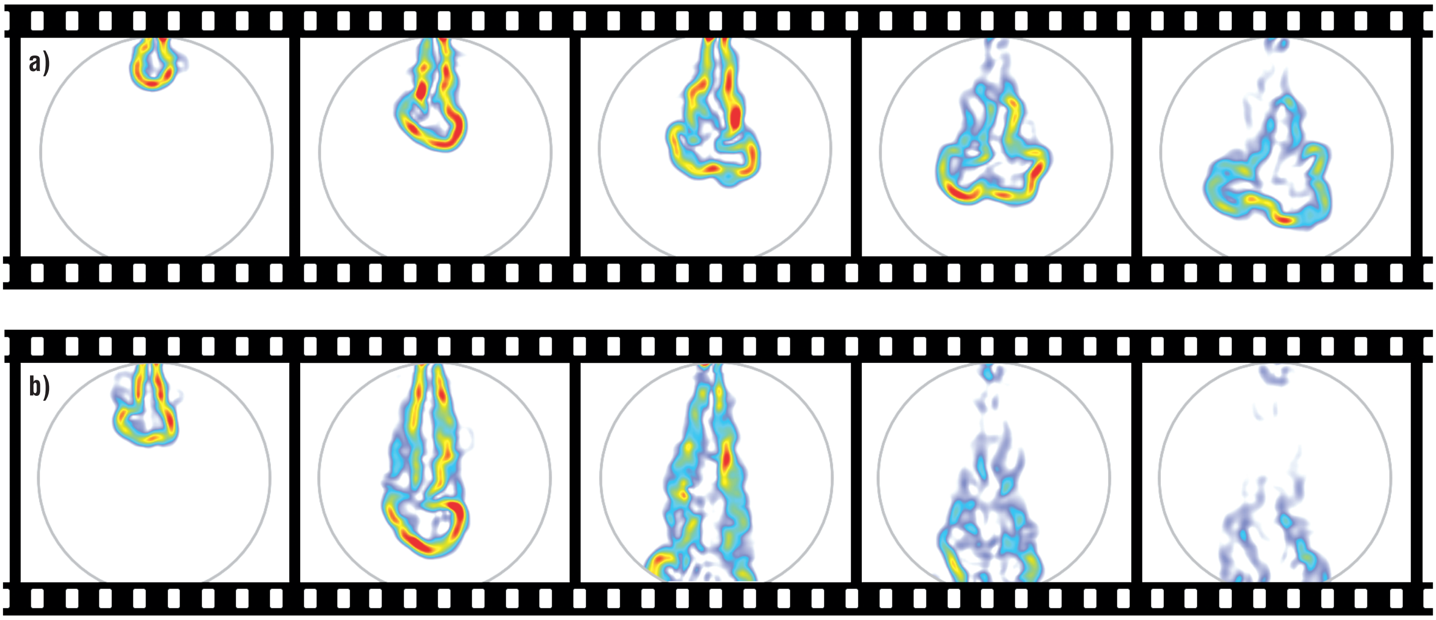

Figure 3: High-speed imaging of hydrogen injection with a) 4 bar and b) 9 bar injection pressure and 3 bar back pressure

Results

Figure 3 clearly shows the different effects of the injection pressure on the distribution of the H_2 during injection, such as different penetration depth and cone angles. LaVisions DaVis software not only enables the visualization of the H_2 gas but also has additional modules for quantitative analysis of the images such as the gas plume geometry, as shown in Figure 4.

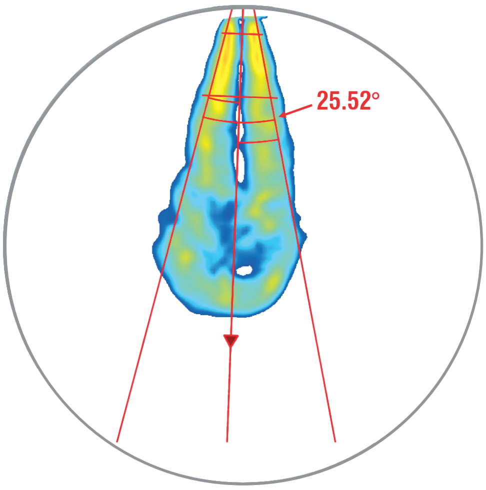

Figure 4: Geometric analysis of gas plume cone angle. The analyzed image is averaged over a number of injections at a fixed crank angle.

The spatial distribution of H_2 and the quantified geometric parameters directly influence the quality of the following combustion and engine out emissions.

The IFKM has shown that the BOS measurement technique is a capable tool for visualizing and quantifying H_2 fuel injection. This is essential for component improvements for hydrogen in IC engines. Developments can be verified efficiently and a validation of simulation models is supported productively.

09/21

LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306