LaVision
FOCUS ON IMAGING

In Application

Water Concentration Measurements in an IC Engine

ICOS-Temperature system applied to compare local and global water concentration

Introduction

Downsizing direct injection gasoline engines at elevated power density involves several challenges of engine design. The use of EGR and water injection has a high potential to deliver a feasible solution between several trade-offs. Both approaches lead to charge cooling allowing for higher compression ratios.

Advantages of EGR and water injection:

- better knock resistance
- lower particulate (PM) and NOx emissions
- higher maximum power and torque
- improved component protection

In addition to the gas temperature, LaVision's Internal Combustion Optical Sensor (ICOS-Temperature) measures crank angle resolved in-cylinder water concentration (Figure 1). This optical indication tool is capable of assisting the development and optimization of water injection and EGR strategies.

Figure 1: *ICOS-Temperature system with M12 spark plug probe.*

Experimental Setup

Two ICOS-Temperature measurement systems are used to simultaneously measure the in-cylinder water concentration in an internal combustion engine to provide global and local water concentrations.

The measurement system is based on the interaction of light with water molecules: Infrared light is absorbed within a certain wavelength range by the presence of water molecules. A light source generates a fast flashing burst of infrared light at 23 kHz.

A built-in spectrometer derives water density, temperature and pressure information from a spectral fingerprint in the light returning from the probe after passing through the measurement section.

To determine the distribution of water during the combustion cycle the two systems measure the water concentration at different locations using two different probes. Local water concentrations at the spark plug position are measured using a spark plug probe which directly replaces the standard M12 spark plug while retaining full spark ignition capability. A second line-of-sight probe is used to measure global water concentration. It measures integrated across the cylinder bore and reveals the mean in-cylinder gas temperature. The setup of the probes is shown in Figure 2.

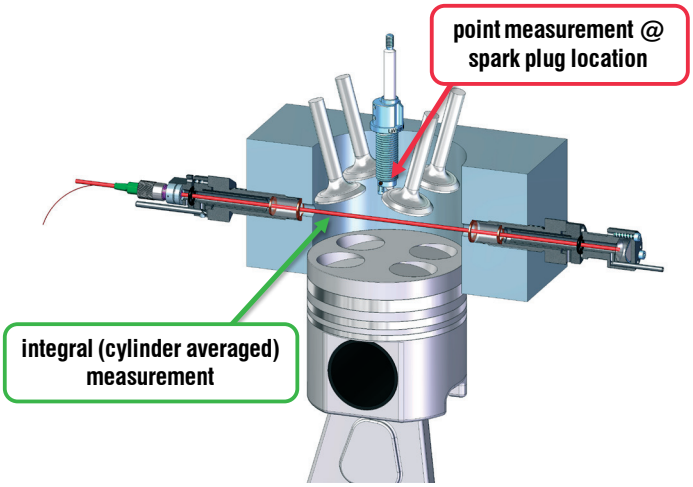

Figure 2: *In-cylinder probe locations M12 spark plug probe and cross-cylinder line-of-sight probe.*

System Features

- highly time resolved for crank angle resolution
- no gas sampling, measures directly inside the cylinder
- precise single cycle analysis
- fully resolved consecutive cycles for measurement on transient phenomena
- choice of non-invasive and minimally invasive probes

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Results

The ICOS systems deliver quantitative water concentration data with crank angle resolution as shown in Figure 3. Differences between local and global water concentration reveal details on the charge motion and mixture formation.

Focusing on the first half of the engine cycle and comparing the global and local water concentrations at the spark plug gives insight into the mixture formation process during air intake and compression strokes. While the global water concentration remains fairly constant once the exhaust gas has been pushed out, the local concentration shows some dynamic features.

While the intake valves are fully open fresh intake air streams past the spark plug. After intake valve closure the water concentration rises above the average level. This is probably due to a volume of residual gas passing the spark plug. During the course of the compression the water concentration at the spark plug approaches the global value indicating an increasingly homogenous mixture.

The example data was measured in a direct injection spark ignition engine without additional water injection or external EGR. The results show the potential of the measurement system for optimizing mixture formation when implementing charge cooling strategies.

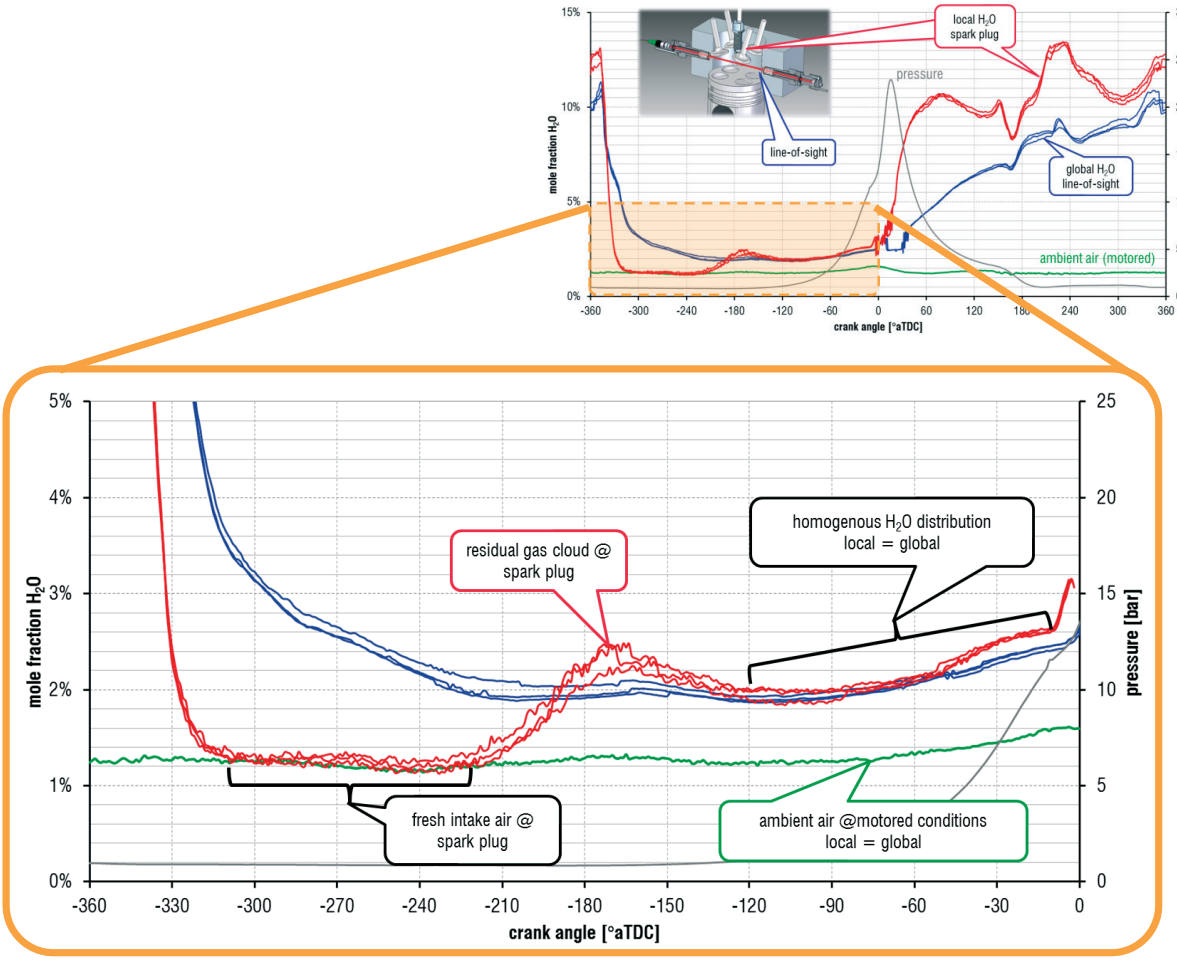

Figure 3: *Optical indication of local and global water concentration in an internal combustion engine during regular operation.*

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