Temporally-resolved spark-induced emission spectroscopy for optical in-cylinder ignition diagnostics

Temporal resolution of spark-induced emission spectroscopy was developed as an optical diagnostics method to monitor ignition of homogenous methane-air mixtures at engine relevant pressure levels in a quiescent constant volume cell. Hydroxyl (OH) emissions at 308 nm, NH emissions at 336 nm and cyanogen (CN) band emissions at 388.3 nm were investigated. Spectral fingerprints of different gas composition were identified to relate plasma emissions to combustion relevant parameters such as the local air-fuel ratio. The temporal-resolved method provides valuable information about the coupling of the electrical discharge characteristics to the measured spectra. Transferring the method to an optical spark plug allows minimally invasive in-cylinder ignition diagnostics.

Introduction

Hydrogen enrichment of methane enhances the ignitability, the flame kernel formation and growth in spark-ignited internal combustion engines. Earlier engine studies demonstrated the benefits and drawbacks of hydrogen enrichment to compressed natural gas on inflammation, combustion duration and benefits and drawbacks of hydrogen enrichment to combustion engines. Earlier engine studies demonstrated the flame kernel formation and growth in spark ignition diagnostics developed as an optical diagnostics method to monitor ignition of the measured spectra.

Experimental test rigs and methods

Spark-induced breakdown spectroscopy (SIBS) is a technique to analyze the availability of different species during ignition [3]. The impact of fuel composition, pressure, temperature and cross-sensitivity on the spectral characteristics are investigated in an optically accessible ignition cell at quiescent conditions and compared with simulated spectra. Experiments were conducted in a small constant volume chamber at an elevated pressure level of 10 bars and compared to pure air and methane emissions. A lens-coupled spectrometer (λ=250 mm) was linked to a high speed intensified and a high speed camera to monitor the plasma emissions during the electrical discharge at a rate of 100 kHz along the spark plug gap of 1 mm as shown in Figure 2. Spectral emissions were captured from the near UV range up to 400 nm. Additionally, a second, higher resolution, long-integrating, classical spark-induced emission spectroscopy setup (λ=320 mm) was used as a reference. Current and high voltage probes on the secondary side of the coil ignition system completed the measurement setup to determine power and energy input.

Optical ignition diagnostics

Significant advances in engine development are currently limited by a poor understanding of the details of ignition and flame development at the early stage of combustion due to the limited optical accessibility of real engines. However, the formation and development of the flame at the early stage of combustion greatly influence the later flame propagation and thus the combustion process and stability. The spectroscopic data of the ignition event enhances the understanding of the transition from the plasma to the early flame kernel and allows to further refine and validate CFD models of the ignition process. Temporal resolved spark-induced emission spectroscopy enables a detailed analysis of the transient behavior of the plasma channel. Integrating this method into an optical spark plug provides insight into the ignition process and can reveal important information on a cycle to cycle basis.