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Hydrogen Enriched Methane – Impact on Ignition and Early Flame Formation

Hydrogen and methane differ drastically in terms of ignitability, reactivity and energy density, flame speed and knocking resistance. By means of …

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Introduction

Hydrogen enriched compressed natural gas (HCNG) engines promise significant advantages in terms of ignitibility, thermal efficiency, reduced cyclic variability and improved applicability to downsizing, supercharging and lean operation concepts. Additionally, HCNG could become a promising alternative fuel for transportation produced from excess electricity generated by fluctuating renewable energy producers such as wind and solar.

A better understanding of the high reactivity, the low ignition energy and the fast laminar flame speed of hydrogen in methane should provide new and useful insights for ignition and turbulent premixed combustion modelling. In this work, methane-hydrogen mixtures were used as a fuel for a better correlation between the hydrogen enrichment of methane and the heat release analysis, as natural gas varies in composition depending on the source it is extracted from.

Experimental test rig

The Rapid Compression and Expansion Machine (RCEM) simulates the compression and expansion stroke of a single engine's cycle. Optical access inside the combustion chamber is granted through a glass in the piston and through windows in the cylinder head, which allows to study the charge motion and the flame propagation with the appropriate imaging equipment. Turbulence is generated by a high pressure air injection at the beginning of the compression stroke. Ignition conditions are fixed to 10 bar and 700 K.

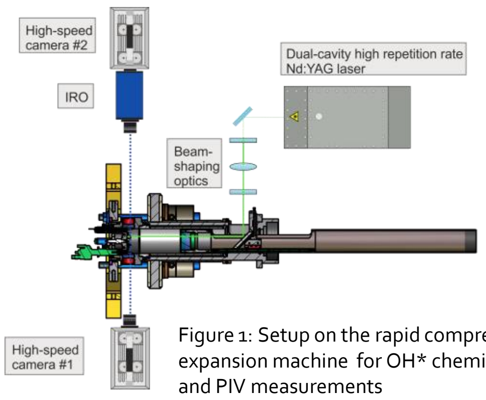


Figure 1: Setup on the rapid compression expansion machine for OH* chemiluminescence and PIV measurements

Methods

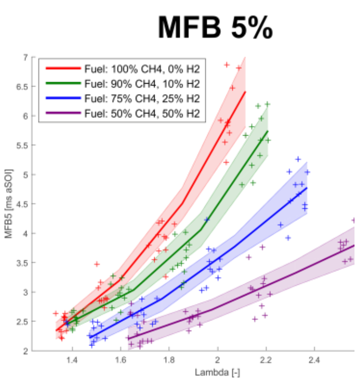
Spark-induced breakdown spectroscopy is a novel technique to analyze the availability of different species during ignition [1].

OH-radical-chemiluminescence is used to track the flame propagation and the combustion process. OH* are excited intermediate species of the chain reactions occurring inside the reaction zone of the flame front during the oxidation of the fuel [2].

Particle Image Velocimetry (PIV) is a widely-used technique in order to measure the velocities of the charge motion's particles in a two-dimensional plane at a specific time. High-speed time resolved PIV measurements (10 kHz) allow to study the temporal evolution of the flow field.

Results

- The effect of hydrogen enrichment on the combustion is higher for a slow flame propagation (lean equivalence ratios or low injection pressure ratios for the turbulence generation).
- Optimizing the injection angle and timing for the turbulence generation in the charge motion improves the interaction of the charge motion with the flame
- For very fast burning cycles (high hydrogen blending ratio or near-stoichiometric λ), the interaction of the charge motion with the flame is lower due to the accelerated flame chemical kinetics



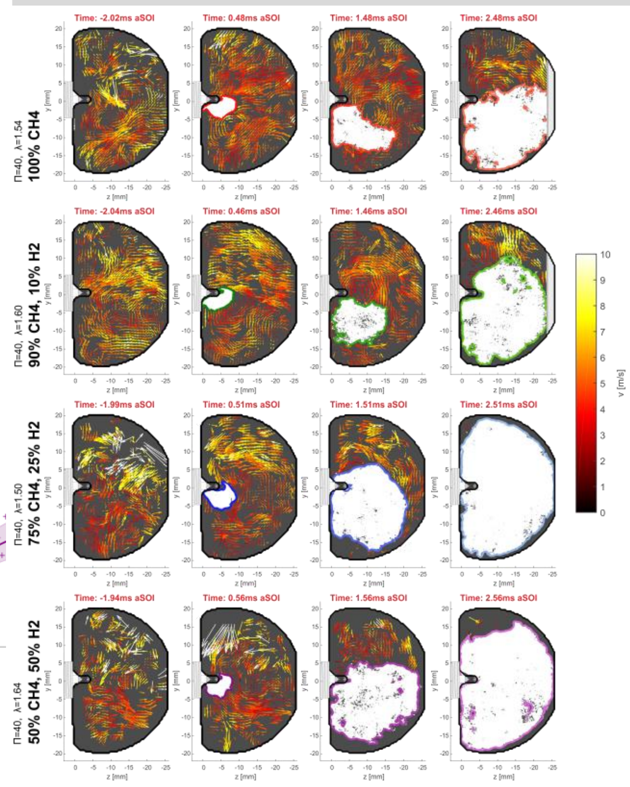


Figure 4: Impact of flow field on the early flame kernel and impact of hydrogen enrichment on apparent flame area

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 data obtained from the experiments is used to validate CFD models, which complement the experimental results due to the limitations of the optical diagnostics, and the results help to understand the physical phenomena of premixed turbulent flame propagation under different operating conditions.

The benefits of understanding the combustion of hydrogen-enriched methane is a main step towards the commercial use of HCNG for the individual mobility, with all the benefits of this alternative fuel compared to conventional fossil fuels.

References

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