

Experimental investigation of oxy-fuel combustion in a HCCI engine

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Abstract

The necessity of performing the energy transition towards renewable energy sources is pushing the scientific community to investigate different solutions for the production, storage and use of energy. Due to intermittent renewable production and their special mismatch between potential and consumption a convenient form for storage and transport is needed. Alongside electricity, the storage and transport of energy will be based on other energy carriers such as e-fuels produced from electricity. The main e-fuels studied are hydrogen, ammonia, methane and methanol. Recovering the energy stored as e-fuels can be done through several routes among which internal combustion engines are a viable and well-developed solution. Between internal combustion engines, it is worth investigating Homogeneous Charge Compression Ignition (HCCI) engines due to their high thermal efficiency and low NO_x emissions [1]. However, the two main limitations of this technology are the low control on ignition timing and the low power density. The first drawback is due to the fact that combustion is driven only by kinetics without any trigger for the onset of combustion. The second one is due to the fact that, as the mixture is homogeneous, combustion occurs everywhere simultaneously in the combustion chamber, leading to the necessity of having low values of equivalence ratio and limited values of compression ratio. In addition to that, as combustion occurs by auto-ignition, and increasing indefinitely the compression ratio is not a viable solution, the intake temperature needed to achieve combustion is high. Several different techniques can be considered to overcome these limitations, among which oxygen enriched combustion. In the context of power to fuel technology, oxy-fuel combustion is very interesting as, during water electrolysis, for each mole of hydrogen produced, half a mole of oxygen is also generated as a side product. Increasing the oxygen fraction in the oxidiser enhances the mixture reactivity, allowing a decrease of the intake temperature and, hence, an increase of the density of the mixture. This would lead to an increase of the operating range, as a higher amount of fuel could be used. However, it has never been investigated how much the enrichment of oxygen can increase the power density in HCCI engines. In this context we have performed a first experimental campaign using a methane fuelled HCCI engine at variable oxygen fractions in the oxidiser. The goal was to map the combustion behaviour at different oxygen content. The main parameters of interests were the intake temperature of the mixture, combustion timing and Maximum Pressure Rise Rate (MPRR). We have also performed a kinetic analysis using OpenSMOKE++ [2] to investigate the chemical reactions driving the combustion behaviour. Finally, a statistical analysis has been performed using JMP to statistically quantify the effects of the different control parameters. It has been experimentally found that increasing the oxygen content in the mixture has a significant potential in decreasing the needed intake temperature of the charge to keep the MPRR in the range from a minimum value of 4 bar/CAD up to the safety threshold of 15 bar/CAD; the decrease of intake temperature registered has been up to 30 K in the range from 21% O₂ content to 49%. Kinetic analysis has highlighted that the mixture is less sensitive to intake temperature changes at higher oxygen percentages. The statistical analysis has confirmed the significance of the interaction effect between the intake temperature of the mixture and the oxygen content.

Keywords: HCCI, engines, oxy-fuel combustion

References

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