Numerical and experimental investigation of methane oxy-fuel combustion in HCCI engines

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1 Context and motivation

The necessity of actuating the energy transition towards renewable resources, drives the scientific community to investigate new energy production and storage techniques; in this context, the power to fuel energy storage technology is a promising alternative, since it allows to convert electricity into different e-fuels. In particular, methane is worth investigating since the infrastructure and the technology to employ it are well developed. The use of methane in Homogeneous Charge Compression Ignition (HCCI) engines represents an alternative for clean and efficient combustion: this technology allows obtaining high thermal efficiency and lower nitrogen oxide (NO_x) emissions with respect to Gasoline and Diesel engines. Furthermore, HCCI engines allow maintaining a certain level of flexibility in terms of fuel adoption. However, this type of technology comes with a number of disadvantages with respect to spark ignition and compression ignition engines, such as the lower power density or the more difficult ignition control. The aim of this work is the numerical and experimental investigation of the potential of oxy-fuel combustion in increasing the power density of HCCI engines.

In an oxy-fuel combustion the nitrogen in the air is partially or totally substituted with oxygen. The main advantage is that fuel consumption is decreased as the heat produced during combustion is not used to increase the temperature of N2, and higher flame temperatures are possible, which leads to a lower level of unburnt fuel emissions. In terms of emissions, when applied to methane, oxy-fuel combustion produces only CO_2 and H_2O; hence, the volume of the flue gases it-self is reduced and this leads to lower heat losses. Moreover, a simpler composition of flue gases allows for easier and less expensive after-treatment systems.

2 Methodology

A 0-dimensional single zone model previously developed in [4] has been used to estimate the mixture intake temperature needed to obtain an optimal combustion (i. e. close to TDC). The kinetic mechanism used is USC 2.0 [1] containing 111 species and 784 reactions, as it has been proved to give the best performances for methane oxy-fuel combustion [2].

Afterwards, an experimental campaign has been conducted at the test bench at Université Catholique de Louvain, equipped with a YANMAR L100V, air cooled, single cylinder engine. A full description of the test bench is given in [3]. All the oxygen percentages from 21% (air) to full oxy-fuel combustion (100% ogygen content) have been tested

3 Preliminary results and future outlook

The first part of the experimental campaign has been conducted keeping a constant intake temperature and fuel content while varying the oxygen percentage. The goal was to quantify the ignition timing shift caused by the increase of oxygen content in the mixture. It has not been found a single intake temperature value for which combustion is occurring at all oxygen percentages (from 21% to 100%). So different intake temperatures for different oxygen content ranges have been selected and the limit conditions have been found for each range. In fig. 1 the pressure curves for oxygen percentages from 36% to 52% are reported, for an intake temperature of the mixture of 402 K.

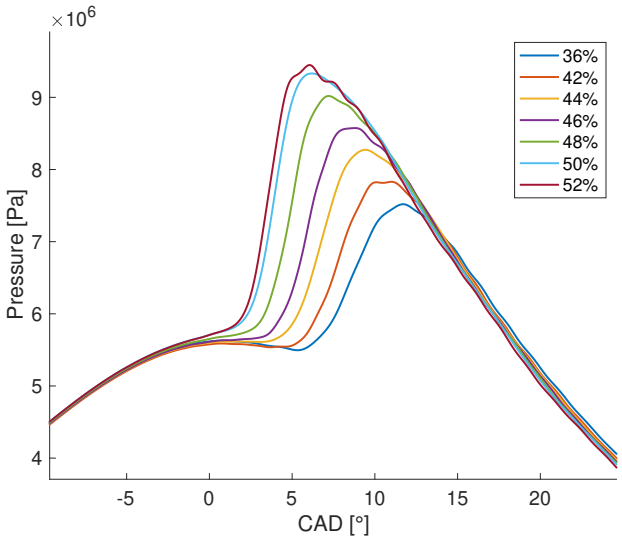

Figure 1: Pressure curve shift in the range 36% - 52% oxygen content

In the second part of the experimental campaign the potential of increasing the fuel content at higher oxygen percentages will be investigated. The combustion timing will be kept constant around TDC in order to compare cases with optimised combustion timings.

References

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