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Effects of reformed fuel composition in “single” fuel reactivity controlled compression ignition combustion

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HIGHLIGHTS

- Reformed fuel/Diesel RCCI combustion is demonstrated.
- Operation at high efficiencies with near zero soot and NOx emissions.
- Reformer for a single fuel RCCI engine does not need to target high H_2 selectivity.
- Hydrogen suppresses LTHR through its interaction with OH radicals.
- High H_2 fractions lead to significant pressure oscillations in-cylinder.

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ABSTRACT

The present effort uses a combination of engine experiments and constant volume ignition delay calculations to investigate reformed fuel RCCI combustion. NOx emissions and efficiency are found to be a strong function of the engine operating parameters and soot emissions decrease with increasing fuel reforming due to a reduction in the mixing requirements of the diesel fuel. The impact of reformer composition is investigated by varying the syngas composition from 10% H_2 to approximately 80% H_2. The results of the investigation show that reformed fuel RCCI combustion is possible over a wide range of H_2/CO ratios. Replacing CO with H_2 resulted in a more reactive charge, decreased the combustion duration, and suppressed low temperature heat release. The suppression of low temperature heat release was explained through consumption of hydroxyl radicals by H_2.

1. Introduction

In recent years, a substantial amount of attention has been devoted to advanced, highly premixed combustion strategies (e.g. homogeneous charge compression ignition (HCCI) and partially premixed combustion (PPC), etc.) [1–3]. These strategies have the potential to achieve high efficiency while keeping engine out emissions low. However, they rely on chemical kinetics to control combustion phasing and duration, having no direct control over the rate of heat release and timing of ignition, which presents practical challenges. Kokjohn et al. [4] showed that the use of two fuels is a promising method to achieve control of this type of combustion. In this approach, named reactivity controlled compression ignition (RCCI) combustion, a low reactivity fuel is premixed with the intake air and a second fuel, with higher reactivity, is direct-injected [5–7]. Combustion phasing is controlled by the ratio of the two fuels and combustion duration is controlled by in-cylinder stratification of ignition delay. Although dual-fuel strategies have shown promising results, the use of two fuels presents challenges for many applications. To avoid the requirement for two different fuels, “single fuel” strategies have been proposed, where gasoline is doped with a cetane improver (e.g., 2-EHN) [8] and used both as the premixed fuel, in its original composition, and direct injected (DI) fuel in its doped version. Although gasoline is the only fuel, there is still the need to handle two different fluids.

Advancements in catalytic reforming have demonstrated the ability to generate syngas (a mixture of CO and H_2) from a single liquid

Abbreviations: AHRR, apparent heat release rate; ATDC, after top dead center; CA, crank angle; CA10, crank angle of 10% mass fraction burned; CA50, crank angle of 50% mass fraction burned; CN, cetane number; DI, direct injected; DOI, duration of injection; EER, effective expansion ratio; EGR, exhaust gas recirculation; EOC, end of combustion; ESU, expansion stroke utilization; FTIR, Fourier transform infrared; GIE, gross indicated efficiency; HCCI, homogeneous charge compression ignition; HRR, heat release rate; HTHR, high temperature heat release; IMEP, indicated mean effective pressure; LTC, low temperature combustion; LTHR, low temperature heat release; MFB, mass fraction burned; PEM, proton exchange membrane; PID, proportional-integral-derivative; PSD, power spectral density; RCCI, reactivity controlled compression ignition; RI, ringing intensity; SOC, start of combustion; SOFC, solid oxide fuel cell; TDC, top dead center; ULSD, ultra low sulfur diesel

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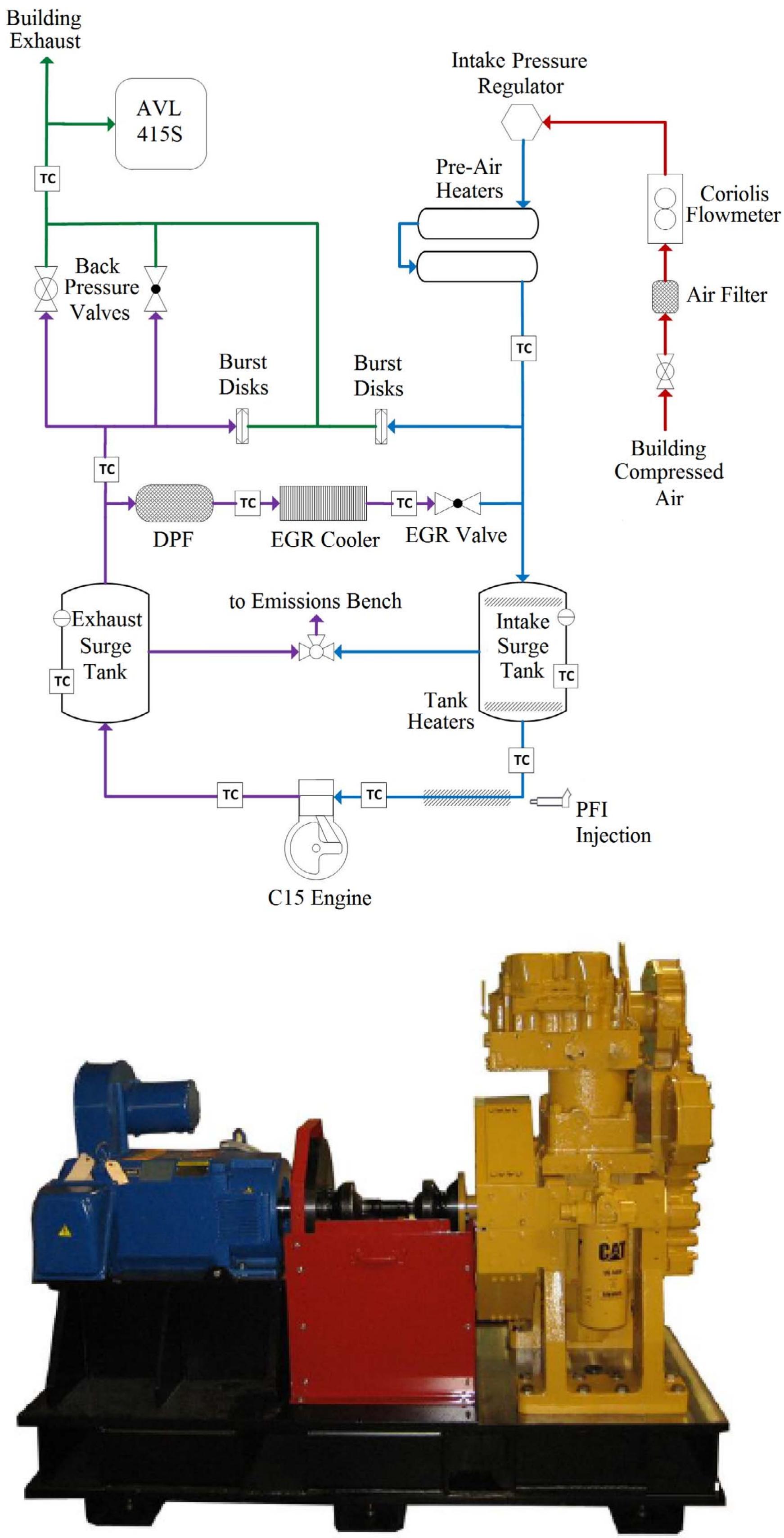

Fig. 1. C15 single-cylinder laboratory schematic (top) and picture (bottom).