Effect of Hydrogen Addition to Natural Gas on HCCI Engine Emissions Using a Single Zone Thermodynamic Simulation

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Abstract

A wide variety of fuels can be used in HCCI combustion engines. The HCCI combustion process is initiated due to auto-ignition of fuel/air mixture which is dominated by chemical kinetics and there is no flame propagation. Therefore fuel composition has a significant effect on engine performance and emissions and a detailed reaction mechanism is generally essential to analysis HCCI combustion. Computational fluid dynamics (CFD) with detail chemical kinetics could be used to study the HCCI combustion of simple fuels, but for most practical fuels it is computationally too time consuming. Single zone model, on the other hand, permit to have a detailed chemical kinetics modeling for practical fuels and it also gives good results compare to experimental data. In this study the effect of hydrogen addition on methane combustion was investigated using a CHEMKIN single-zone model with detail chemical mechanism in order to investigate combustion phenomena and to analyze emissions and the pressure and temperature distributions in an HCCI engine. Ten different mixture of natural gas-hydrogen with hydrogen ranging from 0 to 90 percent is used. The addition of hydrogen in variable concentrations significantly increases the reactivity of the natural gas blend used (methane–ethane 10:1), particularly under fuel-lean conditions. The results indicate that increasing hydrogen portion decreases CO, CO2 and unburned hydrocarbons while it advances ignition timing and enhances peak pressure and temperature.

Keywords: HCCI, Natural gas, Hydrogen, Thermodynamic modeling

Introduction

HCCI is characterized by the fact that the fuel and air are mixed before combustion starts and the mixture auto-ignites due to temperature and pressure increase in the compression stroke. Therefore HCCI engine is similar to a SI engine in the sense that both engines use premixed charge, and it is similar to a CI engine because both rely on auto-ignition to initiate combustion. HCCI combustion of diesel-like fuels like PRF displays a peculiar two-stage heat release, the initial stage of the heat release curve is associated with low temperature kinetic reactions, and the time delay between the first and main heat releases is attributed to the ‘‘negative temperature coefficient (NTC) regime’’ which locates between the two heat release stages [1,2]. There is no discernable flame propagation in HCCI combustion.

The concept of HCCI was initially investigated for gasoline applications in 1979, by Onishi et al. [3] to increase combustion stability of two-stroke engines. They found that significant reductions in emissions and an improvement in fuel economy could be obtained by creating conditions that led to spontaneous ignition of the in-cylinder charge. Stable HCCI combustion could be achieved between low and high load limits with gasoline at a compression ratio of 7.5:1 over the engine speed range from 1000 to 4000 rpm. In 1983 Najt and Foster [4] extended the idea to four-stroke engines and attempted to gain additional understanding of the underlying physics of HCCI combustion. They concluded that HCCI auto-ignition is controlled by low temperature (below 1000 K) chemistry and the bulk energy release is controlled by the high temperature (above 1000 K) chemistry dominated by CO oxidation. HCCI researchers have investigated different fuels such as iso-Octane, ethanol [5-