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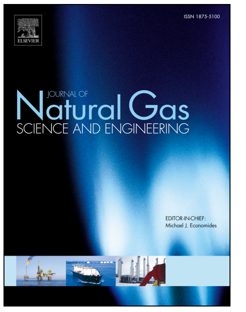

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Effects of oil and water contamination on natural gas engine combustion processes

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Abstract

Abundant availability and potential for lower emissions are drivers for increased utilization of natural gas in automotive engines for transportation applications. A novel bimodal engine has been developed that allows on-board refueling of natural gas by utilizing the engine as a compressor. Engine compression however, results in altering the initial state of the natural gas. Increase in temperature and addition of oil are two key effects attributed to the onboard refueling process. A secondary effect is the presence of water in the natural gas supply line. This study investigates the effect of upstream conditions of natural gas on three parameters - autoignition temperature, ignition delay, and laminar flame speed. These parameters play key roles in the engine combustion process. Parametric studies are conducted by varying the initial mixture temperature, water, and oil content in the fuel. The studies utilize numerical simulations conducted with detailed chemistry for natural gas with *n*-heptane used as a surrogate for oil. Water addition to natural gas at 1–5% by volume did not result in any major changes in the combustion processes, other than a slight reduction in laminar flame speeds. Oil addition of 1—5% by volume reduced autoignition temperature by 5—10% and ignition delay by 27—95% depending on the initial temperature. Sensitivity analysis showed that this was likely due to decrease in the sensitivity of two recombination reactions with oil addition. Evolution profiles of key radical species also showed increasing mole fraction of the hydroperoxy radical at lower temperature that likely aids in reducing the ignition delay. Oil addition resulted in a relatively small increase in the laminar flame speed of 1.7% along with an increase in the adiabatic flame temperature. These results help inform the combustion process and performance to be expected from the bimodal engine.

1. Introduction

There is growing motivation to incorporate natural gas as a fuel for ground transport applications in the United States. Some of the major factors behind this trend include cheap and plentiful availability, widespread supply of natural gas to homes and businesses, high octane content, and environmental benefits from reduced emissions [1]. The higher octane content of natural gas allows engines to operate with higher compression ratios, increasing thermal efficiencies to match or exceed those of gasoline engines [2]. Natural gas has a higher hydrogen-to-carbon ratio than conventional gasoline fuels and this allows for reduced CO_2 emissions. However, advanced strategies are required to keep the NO_x and unburned hydrocarbon emissions within acceptable limits [2-3].

A key barrier to adoption of natural gas as a transportation fuel is the lack of a refueling infrastructure. Fast-fill stations that store compressed natural gas (CNG) and allow for refueling times on the order of five minutes comprise less than 1% of gasoline stations [1]. While liquefaction into liquid natural gas (LNG) is an option, this process is more expensive and complex compared with producing CNG. To overcome the