An Optical Investigation of Diesel-Pilot and Methane Dual-Fuel Combustion

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Abstract –The study investigated dual fuel combustion, where late-cycle diesel-pilot injection ignites the premixed methane-air mixture at light load in a single cylinder heavy-duty diesel engine, modified for optical access. The high-speed natural luminosity technique was employed to visualize the combustion processes at varying methane lambda values and different pilot ratios. Several methane lambda values were tested and to obtain different lambda values, methane quantity was varied while keeping other parameters the same. Methane was injected into the cylinder through intake manifold along with the air. In addition, three different pilot ratios were tested, obtained by varying the diesel-pilot amount. The results show that the flame front propagation becomes more prominent at methane lambda values closer to stoichiometric condition and evidence of flame front propagation could be seen in NL-images. In terms of the pilot ratio, it is observed that an increase in the pilot amount causes a rapid combustion and improves flame front propagation. The trends of ignition delay in dual fuel combustion for conducted tests were also analysed.

1. Introduction

In recent decades, the research and investments in technological advancement in the field of internal combustion engines have mainly been driven by the need for emissions reduction. Dual fuel (DF) combustion in diesel engines consuming methane as a primary fuel, ignited by a small amount of diesel-pilot seems to have potential to reduce emissions and comply with new stringent emission legislations. Methane is the major component of natural gas, typically constituting more than 90% of it and considered a cleaner fuel compared to conventional diesel due to the theoretical reduction of CO_2 resulting from its higher H/C ratio. At lean mixture conditions, highly premixed combustion of methane reduces NOx emission, as the combustion temperature is low. Methane can be applied as a primary fuel source in a conventional diesel engine with a high compression ratio resulting in diesel like efficiency.

A DF engine uses two fuels, typically of different reactivity. In the diesel-methane DF engine, methane as a low reactivity fuel is ignited by a high reactivity, compression-ignited diesel-pilot. The fundamental concept of DF combustion is illustrated in Fig. 1, where liquid diesel-pilot is injected directly into a combustion chamber where it evaporates, mixes with air and ignites by compression. The premixed low reactivity fuel, the methane-air mixture then, burns in the vicinity of diesel-pilot combustion and premixed flame fronts due to methane combustion, propagates throughout the combustion chamber igniting the unburned premixed methane-air mixture and produces a power output. The DF engine can be operated on either DF combustion mode or typical diesel only injection mode [1]. In literature, the term DF may refer to different types of combustion concepts. In the gas-diesel combustion mode, the gas is injected directly into the combustion chamber and burns as it is injected in the same manner as the liquid diesel [1]. Based on the factors of injection timing, the gas lambda value and stratification levels of the in-cylinder mixture at the end of the compression stroke, the DF combustion can be regarded as e.g. PCCI [2] and RCCI [3][4] combustion concepts.