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CHARACTERISTIC OF ENERGY FRACTIONS AND EMISSIONS UNDER NATURAL GAS/DIESEL DUAL-FUEL HEAVY-DUTY ENGINE IN TERMS OF THE COMBUSTION PARAMETERS

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ABSTRACT−In this research, it was investigated the energy fraction and emission characteristics of natural gas/diesel dual-fuel combustion in terms of the combustion index such as combustion duration and mass fraction burned 50 % (MFB50) of a 6-L heavy-duty compression ignition (CI) engine. The reactivity gradient was varied by changing the diesel injection timing and natural gas energy fraction from 60 to 90 %. Engine speed was fixed at 1,200 rpm, and the total input energy from the two fuels was maintained at 11,880 J/cycle for all six cylinders. Diesel injection timing was varied from top dead center (TDC) to 40° before TDC (BTDC) (at intervals of 10°). First, the combustion parameters were analyzed in terms of differences in reactivity gradients. The main combustion parameters considered included ignition delay, combustion duration, and MFB 50. For all cases, the indicated thermal efficiency (ITE) was analyzed with respect to the energy fractions of combustion loss, heat transfer loss, and exhaust loss, to determine the main influences on combustion duration and the MFB 50. Engine-out emission was introduced as an operating parameter associated with ITE and the various losses. These values were compared to those of neat diesel combustion conditions.

KEY WORDS : Combustion duration, Compression ignition engine, Dual-fuel combustion, Ignition delay, Natural gas, Premixed compression ignition (PCI)

1. INTRODUCTION

Dual-fuel combustion technology of compression ignition (CI) engines uses both low- and high-reactivity fuels simultaneously. This technology has been applied to diesel fuel engines to address environmental concerns associated with nitrogen oxide (NOx) and particulate matter (PM) emissions. Conventional diesel combustion is based on the auto-ignition of a heterogeneous mixture of air and diesel fuel, with diesel as the primary ignition source. Duel-fuel combustion uses diesel fuel to ignite a low-reactivity fuel; this preserves the operation and performance of the diesel engine, while allowing the engine to run on a cleaner fuel. The improved homogeneity of the air–fuel mixture significantly reduces PM emission compared with that of conventional diesel combustion (Heywood, 1988; Papagiannakis and Hountalas, 2004). Furthermore, because most dual-fuel combustion is implemented under lean mixture conditions, NOx is also reduced (Liu *et al*., 2013; Wang *et al*., 2016; Kang *et al*., 2018).

However, in terms of thermal efficiency, low-reactivity fuels degrade the combustion efficiency of CI engines due to poor ignitability. The prolonged combustion duration leads to heat transfer loss. Thus, the simple substitution of gasoline for diesel fuel does not provide thermal efficiency comparable to that of neat diesel combustion (Paykani *et al*., 2015; Yang *et al*., 2016). However, compared with high-reactivity fuels such as diesel, low-reactivity fuels have a longer ignition delay. As such, dual-fuel combustion is favorable for premixed compression ignition (PCI) (Inagaki *et al*., 2006; Lee *et al*., 2017a). PCI combustion, with an overall lean air–fuel mixture and rapid combustion, has the merits of low NOx and PM emissions and high thermal efficiency.

Reactivity-controlled compression ignition (RCCI) is representative of PCI combustion concepts. Reitz *et al.* suggested this combustion concept primordially (Splitter *et al*., 2010). Low-reactivity fuel, usually gasoline, is introduced into the cylinder via a port fuel injector (PFI). The fuel is mixed with air and other gases. A small amount of diesel fuel, a high-reactivity fuel, is then introduced before ignition. In general, the split diesel injection strategy comprises early injection of part of the fuel and a second injection for ignition closer to TDC (Curran *et al*., 2010). As opposed to conventional duel-fuel combustion strategies, RCCI combustion is similar to homogeneous charge compression ignition (HCCI) (Hanson *et al*., 2010; Kokjohn *et al*., 2010; Splitter and Reitz, 2014). Most of the

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