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EFFECTS OF PISTON BOWL GEOMETRIES ON DIESEL AND GASOLINE DUAL-FUEL COMBUSTION UNDER LOW LOAD CONDITIONS

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ABSTRACT–This study investigated the combustion characteristics by changing the operating parameters and piston bowl geometries in diesel/gasoline dual-fuel combustion. The experiment was conducted in a light-duty single cylinder diesel engine satisfying the EURO-6 regulation adapted for dual-fuel operation. The engine was operated under a low load condition, which was 1,500 rpm and gross IMEP 5.2 bar, with compression ratio of 14. The effects of the operating parameters, namely, the fuel ratio, diesel injection timing, and pilot duration, were analyzed for three different piston bowl geometries. Based on each result, the optimization experiments were conducted to satisfy the various constraints. The gross indicated specific NOx (gISNOx) was restricted below 0.21 g/kWh, the soot emission was limited to below 0.2 FSN, and the maximum pressure rise rate (mPRR) was confined to below 5 bar/deg. Simultaneously, the gross indicated efficiency (GIE) was controlled over 40 %. As a result, these constraints were completely satisfied in all pistons.

KEY WORDS : Diesel engine, Dual-fuel combustion, Piston bowl geometry, Gasoline, Nitrogen oxides (NOx), Soot emission, Gross indicated efficiency (GIE), Combustion phase

1. INTRODUCTION

Diesel engines have been steadily utilized for decades due to their high thermal efficiency and low carbon dioxide (CO_2) emission. However, as concerns about the environment have increased, regulations on emissions, such as nitrogen oxides (NOx) and particulate matter (PM) which are mainly emitted in diesel engines, have become progressively more stringent (Heywood, 2018). Specifically, the EURO-6c regulation has been implemented since September 2017, changing the driving test cycle from the new European driving cycle (NEDC) to the worldwide harmonized light vehicle test procedure (WLTP), with the addition of the real driving emission (RDE) test. Therefore, the reduction of these emissions has been a main issue of recent studies on diesel engines. Although after-treatment systems such as selective catalytic reduction (SCR), lean NOx traps (LNT), and diesel particulate filters (DPF) have been used to reduce these emissions in diesel engines, they still have problems, such as increasing the manufacturing cost and vehicle weight (Lee *et al*., 2017). Thus, it is necessary to advance combustion with reduced emissions while simultaneously achieving a high thermal efficiency.

Dual-fuel combustion which uses two different fuels can be regarded as a type of advanced combustion technology. Specifically, the reactivity controlled compression ignition (RCCI) concept, which was demonstrated by Splitter *et al*. (2010), uses a low-reactivity fuel (e.g., gasoline) as a premixing and power source and a high-reactivity fuel (e.g., diesel) as an ignition source. The low-reactivity fuel is injected on the intake port by the PFI (port fuel injection) system, while the high-reactivity fuel is directly injected into the cylinder. Because the premixed low reactivity fuel increases the homogeneity of the air-fuel mixture, soot emission can be reduced. Earlier diesel injection timing than that of conventional diesel combustion (CDC) lengthens ignition delay and improves premixed combustion, resulting in shortening combustion duration. In addition, low combustion temperature can be achieved using high EGR rate (Curran *et al*., 2010; Kokjohn *et al*., 2011; Lee *et al*., 2015). As a result, both low NOx and soot emissions and a high thermal efficiency can be acquired (Inagaki *et al*., 2006; Hanson *et al*., 2011; Kang *et al*., 2018). Unlike the CDC, the start of combustion (SOC) timing on the RCCI combustion is not decided by the diesel injection timing but by the degree of reactivity stratification in the cylinder (Kokjohn and Reitz, 2010; Reitz and Duraisamy, 2015).

The piston bowl geometry plays an important role in developing the in-cylinder air flow and furthering the mixing of air and fuel. Hanson *et al*. (2012) demonstrated that as the surface to volume ratio decreases, the increase in the gross indicated efficiency (GIE) can be acquired due to a reduction in the heat transfer loss using a KIVA computational fluid dynamics (CFD) simulation. In addition, it maintained an ultra-low level of NOx and PM emissions.

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