DDFS 조건에서의 희박 PRF/공기/EGR 혼합물의 저반응성 연료 분사전략에 관한 직접수치모사

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DNSs of the effects of low reactivity fuel injection strategies on lean PRF/air/EGR mixtures combustion characteristics under direct duel fuel stratification (DDFS) conditions

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Conventional internal combustion engines utilize high-reactivity fuels (e.g., diesel) via compression ignition in a high-temperature, mixing-controlled, process. Under high-load conditions, this often results in high levels of particulate matter and NO_X. To reduce harmful emissions, low-temperature combustion (LTC) engines are promising solution in engine combustion network (ECN) [1-4]. Homogeneous charge compression ignition (HCCI), one of the earliest LTC strategies, utilizes a fully premixed fuel/air mixture, with a kinetically-controlled ignition which depends on temperature, equivalence ratio, fuel properties, and time [1-4]. Despite the merits of HCCI, there are several significant drawbacks. The main drawback to the use of HCCI engine is a lack of fast-response combustion phasing control parameters which are available in conventional combustion strategies, such as spark and fuel injection timing. Therefore, much of the research on an advanced combustion engine is focused on improving the methods to control ignition timing and operating range [1-7]

Many researches are studied the advanced combustion engine concepts to solve the challenges in HCCI engines [1-12]. To control the overall combustion process, certain direct injection strategies can be carried out. Dividing a single injection into many smaller injections helps to further decrease the noise while suppressing the increase of fuel consumption and emissions [13-15]. Multiple injection strategies in engines generally consist of an early pilot injection of a small quantity followed by main injection and finally by post injection of a small quantity [13-20]. A post injection has been used to reduce unburned hydrocarbon (UHC) from the fuel-lean region, and to increase the oxidation of soot by enhancing fuel-air mixing [18]. However, Bobba et al. [19] noticed that these merits are provided at the expense of a reduction in gross indicated mean effective pressure (IMEPg). Bao et al. [20] elucidated that the close post injection from main injection increases the thermal efficiency.

Table 1 Injection timing and duration, and fuel mole fraction of single and main-post injection strategies

	Single	Post (20%)	Post (25%)	Post (50%)
t_{inj} (ms)	0	0, 2	0, 2	0, 2
t_{dur} (ms)	0.8	0.64, 0.16	0.6, 0.2	0.4, 0.4
n-C_7H_{16}	0.324	0.324	0.324	0.324
i-C_8H_{18}	0.676	0.541, 0.135	0.507, 0.169	0.338, 0.338
PC_8H_{18}	0.676	0.541, 0.135	0.507, 0.169	0.338, 0.338

In this study, the effect of the amounts of main-post injection *iso*-octane on the ignition of a lean primary reference fuel (PRF)/air mixture is investigated (see Table 1). Single, and main-post (80:20, 75:25, 50:50) of *iso*-octane are added to the fuel/air mixture, while keeping the equivalence ratio the same as $\boldsymbol{\phi_0}$ = 0.6. For all DNSs, mean temperature, pressure and are 770 K and 18.2 atm at -25 ° CA ATDC, respectively. In a recent experimental study [21], the RMS of temperature fluctuation in an engine was found to be 13.3 K at TDC which is corresponding to 15 K in numerical simulations. For 2D DNSs, initial value of temperature fluctuation, $\boldsymbol{T'}$ of 20 K, is selected to match $\boldsymbol{T'}$ at TDC with experimental results. To save computational cost, all the simulations start at −25 °CA ATDC, at which the injection of *n*-heptane is assumed to be already finished.

The objective of the present study, therefore, is to provide a better understanding of the effects of the main-post injection strategies on PRF/air mixture using DNSs by varying key parameters: (1) injection quantity, (2) duration under same initial conditions.

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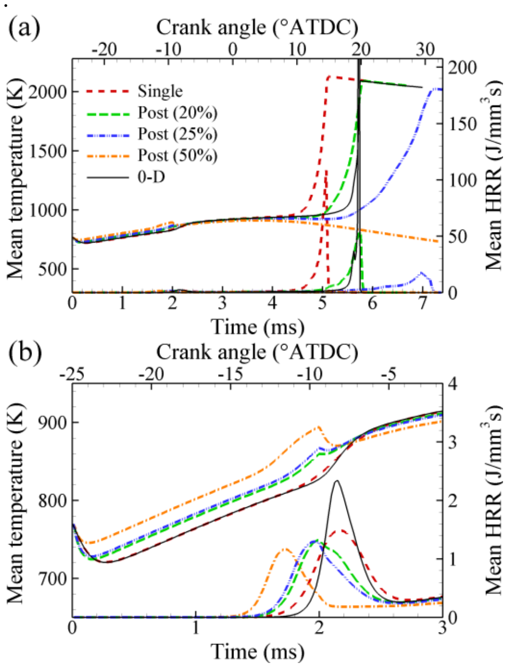

Fig. 1 Temporal evolutions of mean temperature and HRR for main-post injection strategy

Figure 1 shows the temporal evolution of the mean pressure, $\bar{\boldsymbol{T}}$, and HRR, $\bar{\boldsymbol{q}}$, for single and main-post injections. First, the main ignition timing is retarded with increasing the amount of post injection by increasing the evaporation cooling effects. Second, the smaller amount of main injection induces earlier first-stage ignition. The retarded second-stage ignition timings are consequently not affected by the early first-stage ignition. It means that evaporation cooling by post injection strongly suppresses the second-stage ignition. The main-post injection strategies decrease peak HRR, which means the operation range of engines can be extended by the injection strategies. It can improve thermal efficiency of the DDFS combustion engines

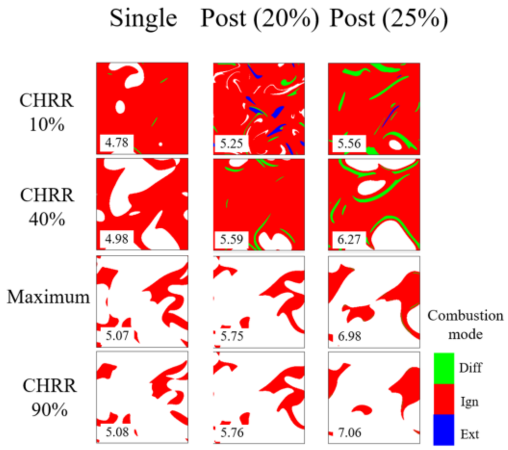

Fig. 2 Isocontours of local combustion modes for single, main-post injection (20, 25 %) strategies (from left to right) at times of 10% (first row), 40% (second row), and 90% (last row) cumulative mean HRR and at the maximum HRR (third row).

Figure 2 shows instantaneous isocontours of cumulative (25%, 50%) and the maximum normalized HRR for different additives injection types. The combustion mode analysis is based on [22]. Assisted-ignition mode is desired because a deflagration wave indicates a unique flame propagation speed, however, the auto-igniting wave arbitrarily large propagation speed. It is readily observed that overall combustion phase is retarded in main-post injection cases. For main-post injection cases, the distinct assisted-ignition mode (green) is observed near the flame front, while for single injection, the auto-ignition mode (red) is dominant.

The effects of main-post injection strategies on the ignition of PRF/air under DDFS

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conditions were investigated computationally by varying injection quantity, and duration of main-post injection. It was found that under same initial mean temperature, pressure and equivalence ratio, the injection strategies enhance the first-stage ignition, but retard main ignition timing due to the separate temperature drop from evaporation cooling. The assisted-ignition mode is predominant for main-post injection cases. It is concluded that main-post injection strategies can improve the operation range from low- to high-load.

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