RCCI 조건에서의 두 헵탄 제트에 대한 직접수치모사

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DNSs of a temporally-evolving twin n-heptane jet under RCCI conditions

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Recently, Jin et al. [1] investigate the ignition and flame characteristics in turbulent pilot ignited DME/methane-air mixing layer under diesel engine-relevant condition. They showed that the triple flame plays an important role during the flame development. In addition, the cool flame and propagation of triple flames are identified.

Previous researches only focused on the single jet ignition characteristics. However, in real engine, the direct-injected fuel is supplied by multi-hole injector thus, there exist several fuel jets during the injection timing. Especially, under late direct injection strategy, the fuel is injected to relatively small volume such as top dead center. Le et al. [2] investigated the effect of jet-jet interactions on soot formation in a small-bore diesel engine. They showed that the soot formation in the fuel rich jet-jet interaction region grows faster and lasts longer due to limited mixing and less chance to the OH-induced oxidation.

Therefore, the objective of this study is to investigate the effect of jet-jet interaction and the fundamental ignition characteristics of a temporally-evolving n-heptane jets within an iso-octane/air charge by performing 2-D DNSs, which is an idealized configuration for RCCI combustion. The effect of interaction between the twin n-heptane jet is elucidated by varying the jet distance, d_{jet}.

For all DNSs, the initial mean pressure, P_0, initial mean temperature, T_0, and the mean equivalence ratio, ϕ_0, are set to be 40 atm, 980 K, and 0.45, respectively. The average fuel is PRF50. To mimic the process of two fuel injections in the RCCI combustion, a lean iso-octane/air charge supplied by the port injection is assumed to be homogeneously distributed through the computational domain while an n-heptane jet by the direct injection is superimposed on the iso-octane/air charge. The two n-heptane jets are assumed to move with a relative-velocity, U_0 = 5 m/s, in the middle of the domain and the distance of two temporally-evolving jet is noted, d_{jet}, consequently inducing inhomogeneities in the composition and temperature fields. Figure 1 shows a schematic of the initial conditions for DNSs. The relative velocity, temperature, and species composition of the n-heptane jet are specified by a top-hat shaped profile function as in [3,4]

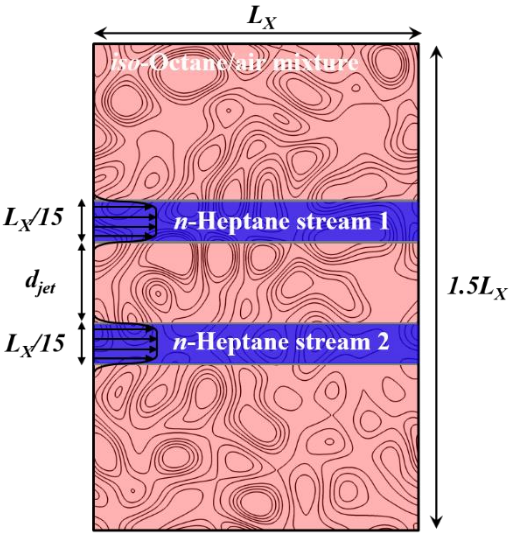

Fig. 1 Schematic of the computational domain.

A 2-D DNS domain of 3.2 x 3.2 mm^2 discretized with 2560 grids points in each direction is used. Such a fine grid resolution of 1.25 μm with a time step of 1.0 ns is required

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to resolve thin flame fronts. A 116-species PRF/air reduced mechanism for PRF oxidation [5] is used and the periodic boundary conditions are applied to all boundaries. To investigate the effect of the jet distance between two n-heptane jet, four different cases were simulated by varying d_{jet}: from cases 1 to 4, d_{jet} = 0, 0.1, 0.9, and 1.9 mm, respectively. The 2-D DNSs were performed on a Cray XC40 system at King Abdullah University of Science and Technology. Each of the DNSs required approximately 0.5 million CPU hours.

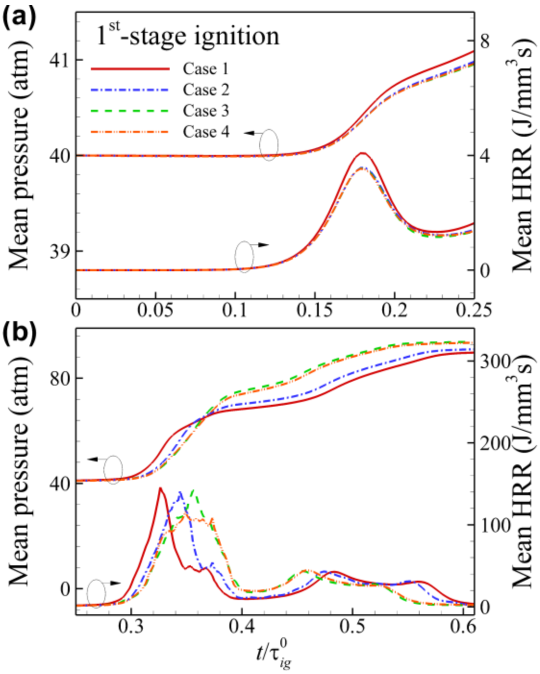

Fig. 2 Temporal evolutions of the mean pressure and the mean heat release rate for Cases 1-4 during (a) the first-stage ignition and (b) the whole combustion process.

Figure 2 shows the temporal evolution of the mean pressure, $\bar{P}$, and heat release rate (HRR), $\bar{q}$, for Cases 1-4. The time is normalized by the 0-D ignition delay, $\tau_{ig,0}$, of 1.54 ms of the PRF50/air mixture. Prior to the detailed analysis of the overall ignition characteristics, it should be noted that from previous DNS studies of RCCI combustion [6,7] without an n-heptane jet, turbulence with large u' and short τ_t is found to effectively homogenize the initial mixture, and hence, the first- and second-stage ignitions are retarded with increasing u' while the peak $\bar{q}$ of the first stage ignition is decreased and that of the second-stage ignition is increased.

Several points are noted from Fig 2. First, the first-stage ignition remains the same in time and the corresponding peak $\bar{q}$ also remains the same with increasing d_{jet}. There is only difference between single jet and twin jet. Second, the start of the second-stage ignition is retarded in time and the duration of overall heat release is decreased with increasing d_{jet}. However, the peak $\bar{q}$ of the second-stage ignition remains the same with increasing d_{jet}. Third, it is also readily observed that there exists a third and fourth peak of $\bar{q}$ for all cases. The third- and fourth-stage ignitions are advanced and the peak of $\bar{q}$ is slightly increased with increasing d_{jet}. Fourth, the effect of d_{jet} on the overall combustion is weakened with increasing d_{jet}.

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