Numerical Simulations of Spontaneous Ignition of Mono-disperse Fuel Spray in Lean Premixed Gas

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Abstract

Spontaneous ignition of mono-disperse fuel spray with uniform droplet distribution in hot fuel/air premixed gas was simulated through one-dimensional numerical model of an isolated fuel droplet in a closed constant-volume cell. Namely, the inter-droplet interaction in a spray was expressed through the interference of the outer boundary of the cell. Equivalence ratio calculated from initial amounts of fuel in the liquid phase and oxygen in the gas phase was defined as liquid-phase equivalence ratio ϕ_l. Since the premixed gas was fuel-lean, the existence of the droplet might either promote the ignition through a role as fuel source or hinder the ignition through a role as heat sink, which could depend on initial droplet diameter d_0, ϕ_l, initial gas-phase temperature T_{g0}, initial liquid-phase temperature T_{l0}, gas-phase equivalence ratio ϕ_g and initial pressure P_0. The effects of the first three conditions were examined. d_0 was less than 200 μm and typically around 30 μm. T_{l0}, ϕ_g and P_0 were 300 K, 0.4 and 3 MPa, respectively. Fuel was *n*-heptane. Detailed chemical kinetics including the low-temperature oxidation reactions were employed, and therefore cool-flame ignition delay τ_{cf} and hot-flame ignition delay τ_{ig} were evaluated. First, only d_0 was varied. When d_0 was relatively large, both τ_{cf} and τ_{ig} were not different from those of only premixed gas with the same ϕ_g. It means that such large droplet required relatively long time for vaporization compared with chemical characteristic time, and the ignition occurred at the outer boundary of the cell that the fuel vapor from the droplet did not reach. However, as d_0 decreased, τ_{cf} and τ_{ig} increased and decreased, respectively, first. Thus interaction between spray and premixed gas was recognized. Next, only ϕ_l was varied. With increasing ϕ_l, τ_{ig} either increased monotonically or had minimal value depending on T_{g0}.

Key words: fuel spray, spontaneous ignition, cool flame, numerical simulation

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