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燃料液滴列における冷炎伝播に関する数値解析

Numerical Analysis of Cool Flame Propagation in Fuel Droplet Array

〇池澤英明 [1], 家村和輝 [1], 齊藤允教 [1], 菅沼祐介 [1], 田辺光昭 [1], 野村浩司 [1]
〇**Hideaki IKEZAWA [1], Kazuki IEMURA[1], Masanori SAITO[1] , Yusuke SUGANUMA[1], Mitsuaki TANABE[1], and Hiroshi NOMURA[1]**
1 日本大学，Nihon University

1. Introduction

In spray combustion, which is used in internal combustion engines such as liquid rocket engines and gas turbine engines, spontaneous ignition may be in two-stage in which a cool flame is generated followed by a hot flame. Cool flame affects the induction time of hot flame[1)]. Clarifying the cool flame is important to clarify the mechanism of spray combustion. Saito et al. showed the cool flame may propagate by heat conduction in the spontaneous ignition process of fuel droplet array[2)]. Mikami et al. showed flame spread limit distribution depends on the burning lifetime of interacting droplets[3)]. Gunji et al. showed experimental device has been developed to observe cool flame propagation[4)]. In this study, numerical simulation of cool flame propagation in a fuel droplet array is to be shown.

2. Simulation Conditions and Method

Table 1 and **Figure 1** show the conditions and a numerical domain. The calculation is conducted as a two-dimensional unsteady solution. The bottom side of the region in **Fig. 1** is the axisymmetric boundary. Other boundaries are adiabatic walls. The fuel is n-decane ($C_{10}H_{22}$), and the liquid properties of the fuel are given inside the droplet. The reduced chemical reaction mechanism including 287 reactions among 77 species is employed[5)]. The droplets are defined as d_1~d_9 from left to right. A spherical hot spot is set at 1.5 mm away from the d_9 droplet and a heat is added on the surface of the spot to induce cool flame propagation.

Table 1 Simulation conditions

Ambient Temperature T_a [K]	300
Ignition Area Surface Temperature T_{ia} [K]	1000
Ambient Pressure [MPa]	0.101325
Ambient Gas Composition [mol%]	O_2 : 21, N_2 : 79
Number of Droplets	9
Inter-Droplet Distance S [mm]	4
Droplet Diameter [mm]	1
Ignition Area Diameter [mm]	0.5

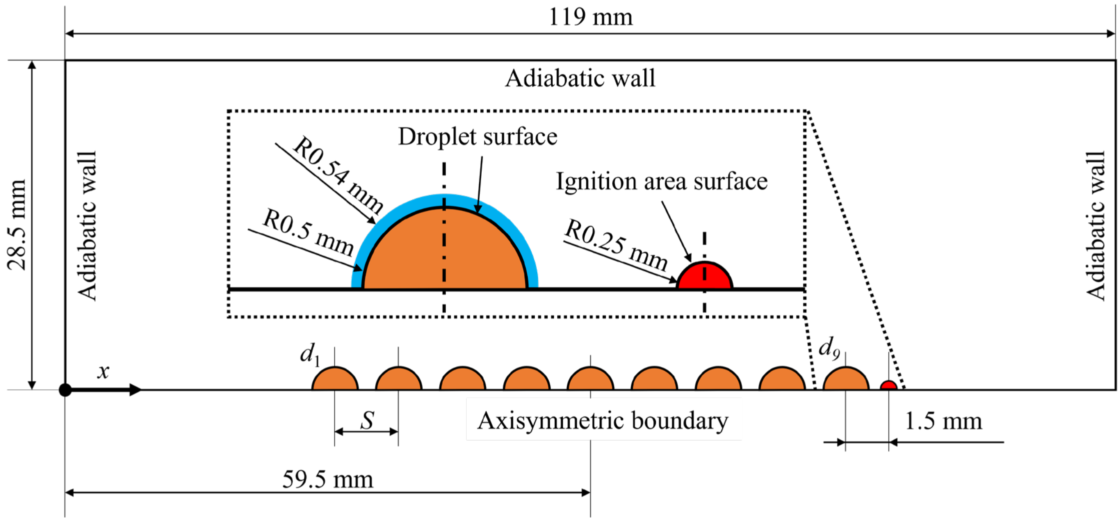

Fig. 1 Numerical domain

3. Results and Discussion

Figure 2 shows the history of the maximum mass fraction of CH_2O and the rate of increase of the mass fraction of CH_2O. In this figure, oscillations are observed. This oscillation is due to the fact that the fuel evaporated from d_9 is supplied to the ignition area, and reaction is locally activated due to the heat of the hot spot. The highest peak of the mass fraction of CH_2O is at 16.4 s. It is not possible to see the behavior of the cool flame in this figure. Therefore, the distribution of temperature and other parameters need to be investigated.

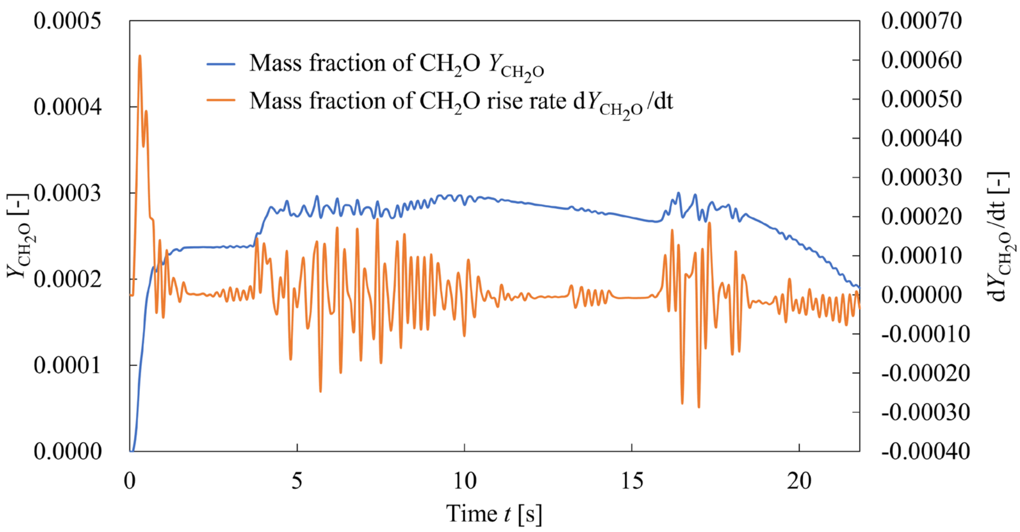

Fig. 2 History of maximum mass fraction of CH_2O and mass fraction of CH_2O rise rate

Figure 3 show the temperature and CH_2O distributions. While the high temperature region due to the ignition source are seen on the right side of d_9, significant difference for the both distributions was not observed. The CH_2O distribution near the ignition area at 21.8 s is smaller than at 16.4 s. In addition, the diameter of d_9 decreases with time, and it is assumed that the droplet disappears at 21.8 s. These results suggest that the heat given to the ignition region caused the fuel to evaporate, and that the evaporation was completed before the cool flame is ignited.

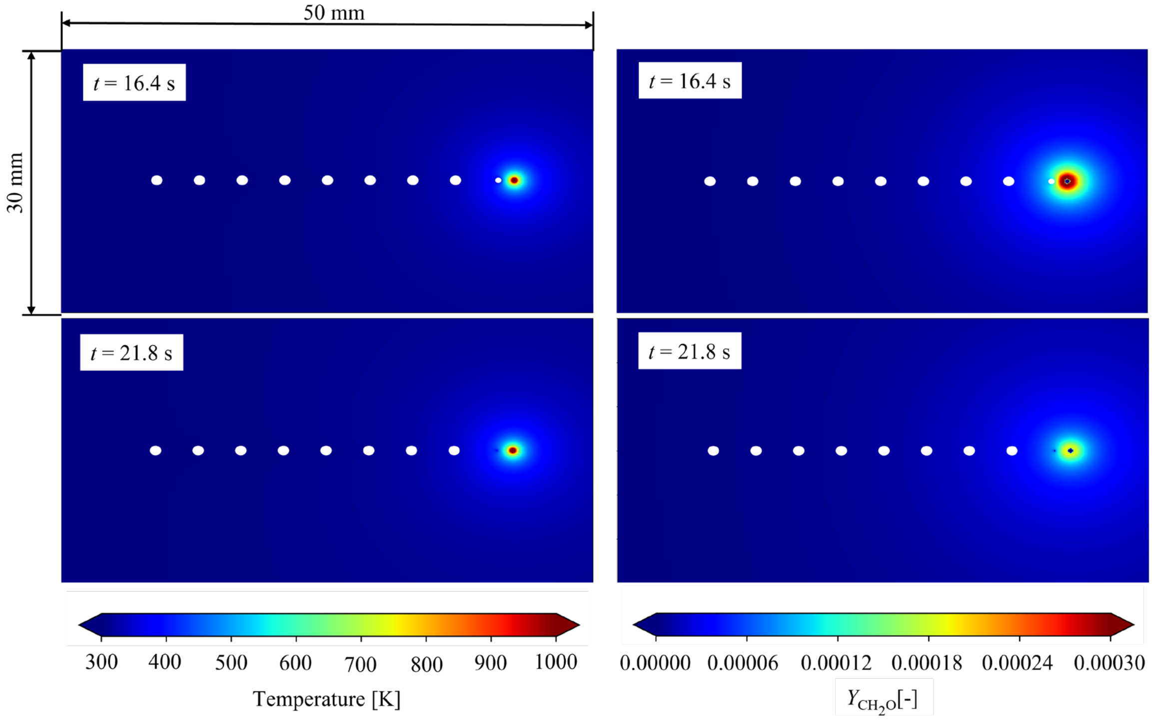

Fig. 3 Temperature (left column) and CH_2O (right column) distribution

Figure 4 shows the histories of each droplet diameter squared. The d_9 is the closest droplet to the ignition area and its diameter decreases, while the other droplet diameters do not. At 21.8 s, the diameter of d_9 is 0 mm, suggesting that all the fuel has evaporated. The temperature on the right side of d_9 at 21.8 s is about 500 K. The HCHO distribution is high, but the fuel has all evaporated, and the evaporation rate of the droplet is higher than the burning rate of d_9 due to the heat from the ignition area.

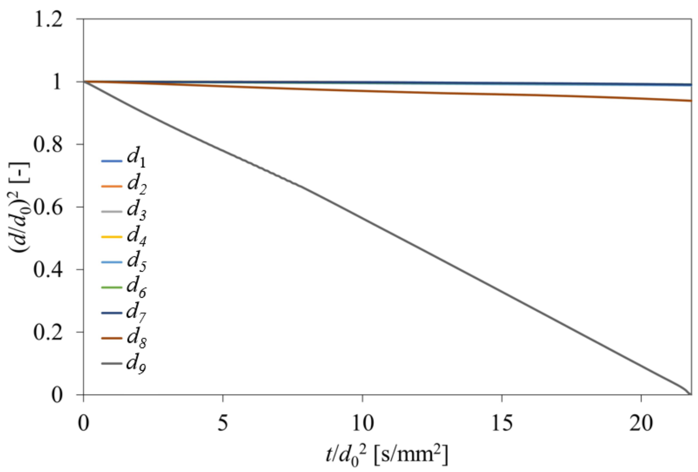

Fig. 4 Histories of each droplet diameter squared

Summary

Numerical simulation model of cool flame propagation through droplet array is developed.

Acknowledgments

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