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数値計算で模擬された燃料液滴列で生じる冷炎のダイナミクスに対する変分自己符号化器の適用可能性

Applicability of Variational Auto-Encoder for Numerically Simulated Cool Flame Dynamics Occurred around a Fuel Droplet Array

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As part of the PHOENIX-II project[1)], an international collaboration between Germany and Japan, the dynamics of cool flame was predicted from two-dimensional axisymmetric calculations with unsteady heating of a fuel droplet array. Compared with a single droplet, multiple droplets contain complex phenomena due to the oscillation of individual droplet. For this reason, it is difficult to create a phase plane in which the trajectory does not intersect. **Figure 1** shows the maximum temperature in the computational domain. As shown in the **Fig.1**, the figure contains oscillations with large amplitude and those with small amplitude.

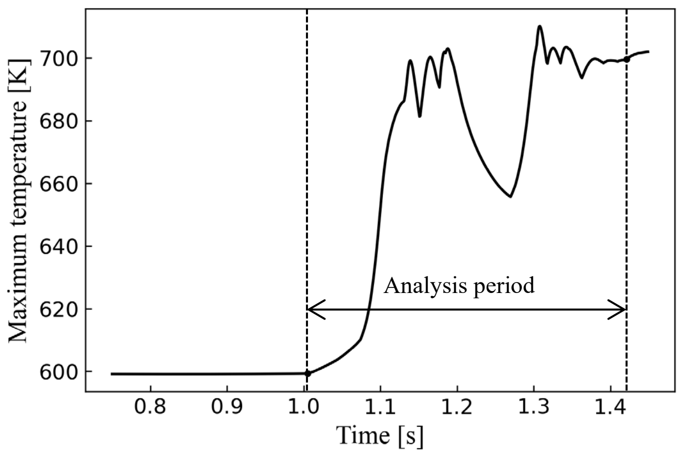

Fig.1 Cool flame oscillation in 9 droplets array (P = 0.1 MPa, T_a = 600 K, fuel: *n*-decane, d_0 = 1.0 mm, T_0 = 300 K)

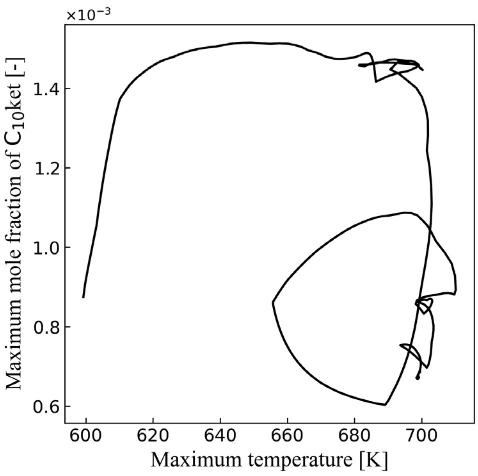

Fig.2 Phase plane by maximum temperature and maximum mole fraction of C_{10}ket

Some phase planes of cool flame oscillation consist of concentration and temperature. **Figure 2** shows the phase plane consisting of the maximum temperature and the maximum mole fraction of ketohydroperoxides (C_{10}ket). As shown in **Fig. 2**, the phase plane of the cool flame oscillation is modeled after F.E. Alam et al.[2)] but the spatial distribution is not considered. Mode decomposition by POD was conducted as an analysis considering spatial distribution, but the trajectory intersected on the phase plane[3)]. In order to clarify the state of individual droplet, the Variational Auto-Encoder (VAE), which was used by Tanabe[4) 5)] in the reduced dimension analysis on combustion dynamics, was applied as the improved method in this study.

The analysis period of VAE is from 1.005 s to 1.420 s as shown in **Fig.1**. The input data is chronological data of spatial distribution of temperature and those of mass fractions of H, OH, CH_2O, $C_{10}H_{20}OOH$, $OOC_{10}H_{20}OOH$, and C_{10}ket among the species that may contribute to cool flame appearance. The input data was learned by VAE and their dimension were reduced. The obtained latent space consisting of the two latent variables Z_0 and Z_1 which was the output of the encoder of the VAE. **Figure 3** shows the trajectory on the latent space obtained from the VAE, and **Fig. 4** shows temperature and C_{10}ket map at A to E on the latent space obtained from the decoder of the VAE considering **Fig. 2**.

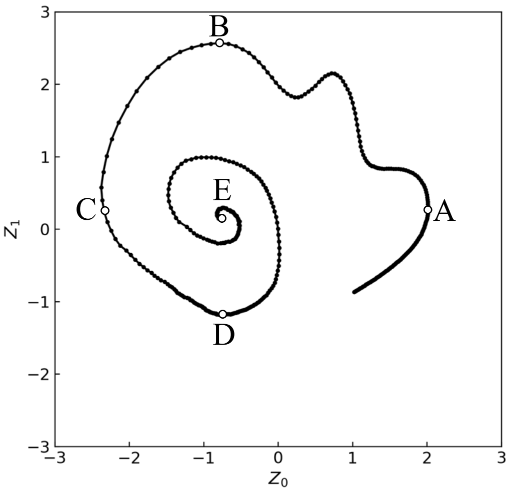

Fig.3 Latent space by VAE

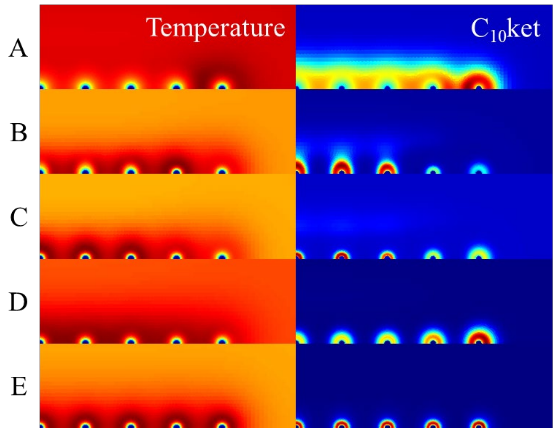

Fig.4 Temperature and C_{10}ket map at A to E on the latent space

Figure 3 shows that the trajectory does not intersect with each other. VAE has the function of classifying phenomena according to their distance and direction from the origin. Based on this principle, unique features are distributed from A to D on the trajectory, and **Fig. 4** shows that the state of the droplet can be classified at each point in the latent space. Therefore, **Fig. 4** may be the latent space that appropriately classifies the states of the dynamical system. VAE is expected to be effective in clarifying the process of cool flame oscillation for it can classify the states of individual droplet.

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