SUBTASK 3.1E

EXPERIMENTAL AND NUMERICAL STUDIES OF HIGH INTENSITY COMBUSTION

Contributor: Japan National Committee for IEA/CRD Implementing Agreement on Energy Conservation in Combustion (JECC), Tokyo, Japan.

Description

The objective of this task is to obtain fundamental information, which can be useful for designing a high intensity compact industrial combustion system. For this purpose, the turbulence-combustion interaction in extremely strong turbulent flow and combustion behavior in the combustion chamber of internal combustion engines have been studied experimentally and numerically. Two topics on high intensity combustion have been conducted in this subtask. One is the knocking combustion behavior in spark ignition engines, and the other is modeling of turbulent premixed combustion by DNS database.

Accomplishment

1. A numerical simulation of the effect of electric fields on knocking combustion will be developed. At the first stage, the equations defining the charge density, electric field, electric potential and the drift velocity of charged particles are included in the simulation code of gas phase reacting flows. To confirm the validity of the developed numerical simulation, the acetylene/air counter flow flame formed by a porous cylinder in electric fields is simulated and the comparison between experiment and prediction is conducted. As a result, the prediction shows that the flame region is shifted to the negative electrode side in electric fields, which is agreement with the experimental results (Figs. 1 and 2).
2. A numerical analysis was performed using DNS (Direct Numerical Simulation) databases of statistically steady and fully developed turbulent premixed flames with different density ratios and with different Lewis numbers. Firstly, local flame surfaces at a prescribed progress variable were identified as local three-dimensional polygons. And then the polygon was divided into some triangles and local flame areas were evaluated. The turbulent burning velocity was evaluated using the ratio of the area of a turbulent flame to that of a planar flame and compared with the turbulent burning velocity obtained by the reaction rate. As a result, for unity Lewis number, the turbulent burning velocity evaluated by the flame area agrees with that by the reaction rate independent of the density ratio, while for non-unity Lewis

number, the turbulent burning velocity obtained by the reaction rate increases or decreases by the extent which the Lewis number contributes. Secondary, local burning velocities over the flame surface were evaluated, and then the probability density functions (pdfs) of local burning velocities were obtained. For Le = 0.8, 1.0, the peak of the pdf is located at a higher value than the un-stretched local burning velocity, while for Le = 1.2, it is located at a lower value than the un-stretched local burning velocity. (Figs. 3 and 4).

Plans

1. The numerical simulation on the knocking combustion including the electric fields will be developed. The numerical simulation code on the droplet combustion in electric fields will be also developed to explore the effect of electric fields on the combustion behavior of liquid fuels.
2. Accurate modeling for scalar dissipation rate will be needed to elucidate turbulent reaction rate and scalar diffusion in turbulent flames. DNS with larger Reynolds number will also be needed to elucidate the effects of turbulent intensity.

Publications

1. K. Yamashita, L. Xie, O. Imamura, J. Osaka, M. Tsue and M. Kono, Diffusion Flame Behavior by a Burner of Porous Cylinder in Electric Fields, J. of Japan Soc. for Aeronautical and Space Sciences, 54-633, pp. 455-469, (2006).
2. K. Tsuboi, S. Nishiki, and T. Hasegawa, An Analysis of Local Quantities of Turbulent Premixed Flames Using DNS Databases, Journal of Thermal Science and Technology, vol. 3, No.1, pp. 103-111, (2008).

Milestone Chart

CY06	CY07	CY08	CY09	CY10
a+		b+	c0	e0
e+		f+	g0	

a. Development of numerical simulation on effect of electric field on diffusion flames.
b. Development of numerical simulation on knocking combustion.
c. Development of numerical simulation on effect of electric field on combustion of liquid fuel.
d. Prediction of the effect of electric fields on sooting behavior in droplet flames

e. DNS of Turbulent Premixed Flames.

f. Development of Models for Turbulent Kinetic Energy and Turbulent Scalar Flux.

g. Verification of Models by DNS with larger Reynolds number.

<u>Contact for Further Information</u>

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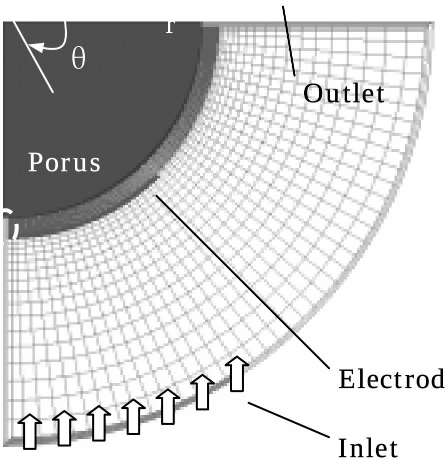

Fig.1 Computation region.

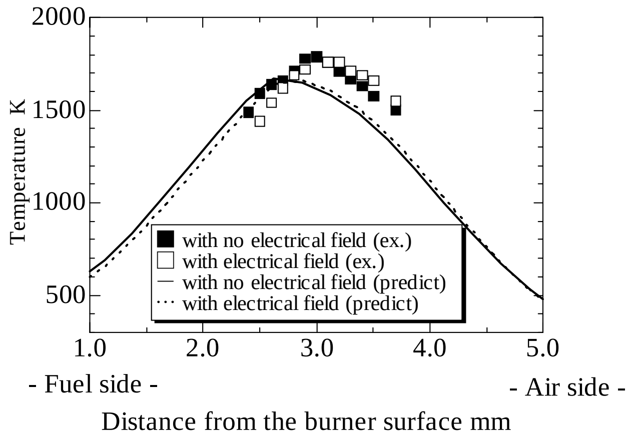

Fig. 2 Temperature distribution.

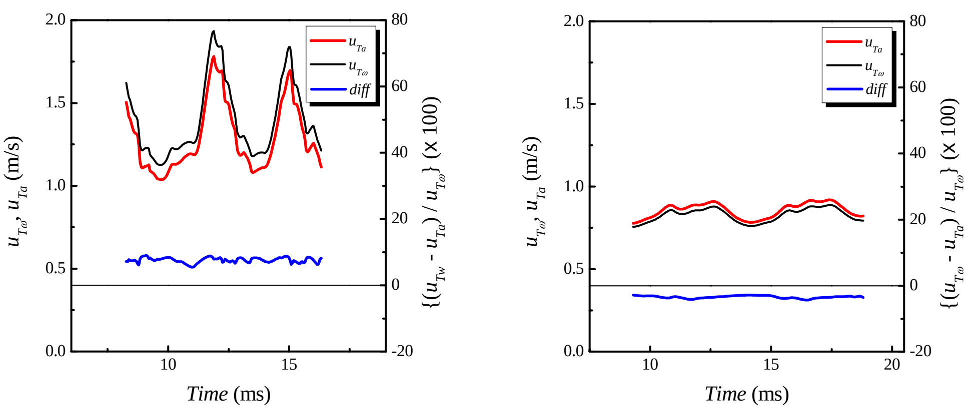

Fig. 3 Comparison of u_{Ta} and $u_{T\omega}$ for Le = 0.8 and 1.2; ρ_u/ρ_b = 5.00.

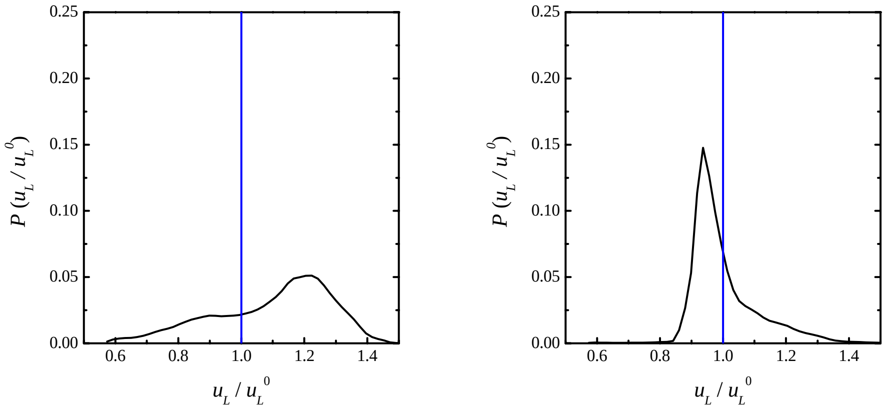

Fig. 4 Evaluation of local burning velocities using pdf for Le = 0.8 and 1.2; ρ_u/ρ_b = 5.00.