§27. Study on Dynamics and Statistical Laws in Turbulence with Active Scalars

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To predict and control high-Reynolds-number turbulence with active scalars, we need to understand the statistical properties and flow structures of such high Reynolds number turbulence. Direct numerical simulation (DNS) of turbulence is one of the most effective tools for such purposes because we can obtain detailed information of the statistical properties and flow structures of such complicated phenomena. Recent development of supercomputers enables us to perform DNS of turbulent flows with huge degrees of freedom.

In the last year, we made several presentations summing up our findings[1)] and published a journal paper[2)]. Also, by performing the DNS of the autoignition process of n-heptane pre-mixture in three-dimensional homogeneous compressible turbulence using a reduced chemical kinetic mechanism, we remarkably developed our understanding of the mutual interaction between turbulence and chemical reactions (with heat release). In the following, we summarize our recent studies based on the DNS of the autoignition process.

To understand the mutual interaction between turbulence and chemical reactions, we performed the DNS of several autoignition process cases of n-heptane premixture. The turbulent flow with chemical reactions was compared with the turbulent flow without chemical reactions. Also, the chemical reactions with turbulence as the initial condition, were compared with the chemical reactions without turbulence. We studied not only several statistical quantities including the energy spectra and the spectra of temperature fluctuation, but also the time-development of the membranal structures of the regions of high rate of heat release. Our findings are as follows.

1. In the case of turbulence with chemical reactions, energy spectrum at high wave numbers is small as compared with the case of turbulence without chemical reactions, which indicates that the chemical reactions with heat release suppress the growth of small scale fluctuations. Visualization of the temperature as well as the second invariant of velocity derivatives suggested that the growth of small scale fluctuations is suppressed at high temperature regions where viscosity is high.

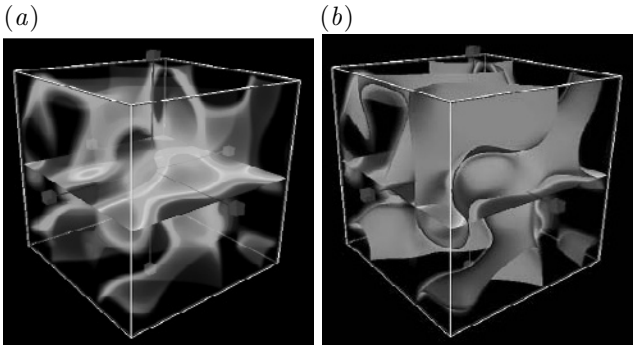

Fig. 1: (a) Membranal structure of the regions of strong exothermal reaction in the autoignition process of n-heptane pre-mixture in 3D homogeneous compressible turbulence.(b)Iso-surface of temperature (870K).

2. In the autoignition process of n-heptane premixture, the regions of strong exothermal reaction form membranal structures, and travel from high temperature regions to low temperature regions (see Fig.1(a)). Detailed visualizations suggest that this fact is true regardless of the presence or absence of turbulence. Also, the detailed analyses showed that the peak positions of heat release agree well with the positions at which temperature is approximately 870K (see Fig.1(b)).

3. A time history of average temperature in the turbulence with chemical reactions is similar to that obtained in zero-dimensional case, i.e. homogeneous reactions. This fact indicates that turbulence has effects of making temperature fluctuations not only complex but also homogeneous.

1) Teraji, A., Ishihara, T., Kaneda, Y.: Proc. COMODIA2012 (2012) 152-157.

2) Teraji, A., Ikuta, H., Miki, T., Ishihara, T.: JSME **79** 799 (2013) 431-438.