§19. Analysis of Coherent Structures and Development of Turbulence Modeling in MHD or HD Turbulence

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We examined small-scale statistics of three-dimensional (3D) homogeneous incompressible magnetohydrodynamic (MHD) turbulence, and developed a multi-scale simulation method for 3D MHD turbulence using orthogonal wavelets. This method is called coherent vorticity and current density simulation (CVCS). We also examined autoignition process in a homogeneous n-heptane mixture in 3D hydrodynamic (HD) compressible turbulence with chemical reactions, performing direct numerical simulation (DNS) of this HD turbulence. In the following, we summarize the achievements of these studies.

3D incompressible MHD turbulence

The journal papers[1, 2] were published. It is shown that the Eulerian acceleration becomes more intermittent as scales decreases than the Lagrangian acceleration in MHD turbulence.[1] This is in contrast to the case of HD turbulence which exhibits extreme intermittency of the Lagrangian acceleration compared to the Eulerian acceleration.

In Ref. 2, we developed the CVCS method to track the time evolution of coherent vorticity and current density in 3D MHD turbulence. CVCS was assessed for a 3D forced homogeneous MHD turbulent flow in comparison to a DNS of the same flow. It is found that, as long as translation of coherent flow and small-scale generation are tracked by the use of a safety zone in wavelet space, CVCS well preserves turbulent statistics, e.g. kinetic and magnetic energies, probability density functions of vorticity and current density, with a reduced number of degrees of freedom.

3D HD compressible turbulence with chemical reactions

We have developed a parallel code of the DNS of the autoignition process of n-heptane pre-mixture in two-dimensional (2D) and 3D homogeneous compressible turbulence using a reduced chemical kinetic mechanism (with 33 chemical species). (See Ref. 3 for the details of the 2D DNS). We have also performed several 2D and 3D DNS's on 256^2 and 256^3 grid points, respectively, to verify their numerical results. We have found the followings from a series of the DNS's.

1. There is no remarkable difference of the time history of average temperature in 2D and 3D cases, when the initial average temperature is the same. However, depending on the difference in the time-evolutions of the energy spectra, the time-evolutions of temperature spectra are different in 2D and 3D cases (although the temperature spectra are initially the same); in 2D case the large scales of temperature grow, while in 3D case, the small scales of temperature tend to grow.

2. In 3D case, temperature fluctuations become small (due to homogenization) when velocity fluctuations in turbulence are strong.

3. In the autoignition process of n-heptane pre-mixture in 3D turbulence, the regions of strong exothermal reaction form membranal structures (Fig.1), and travel from high temperature regions to low temperature regions.

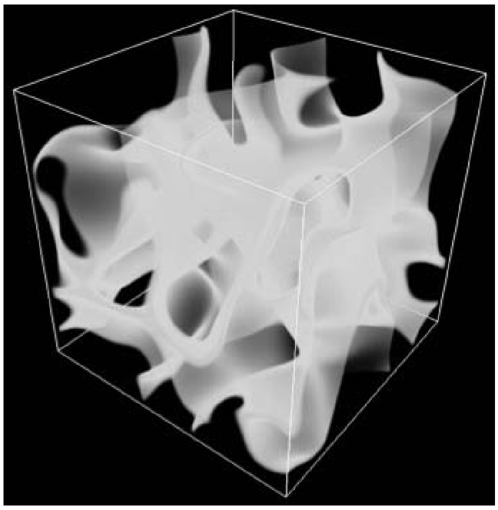

Fig. 1: Membranal structure of the regions of strong exothermal reaction in the autoignition process of n-heptane pre-mixture in 3D homogeneous compressible turbulence.

1) Yoshimatsu, K. et al.: Phys. Plasmas **18** (2011) 092304.

2) Yoshimatsu, K. et al.: Fluid Dyn. (2012) DOI:10.1080/03091929.2012.654790.

3) Teraji, A. et al.: JSME **77** 779 (2011) 1592.