§39. Investigation on the Mechanism for Suppression of Turbulence Generation in Compressible Flows

Horiuti, K. (Tokyo Inst. Tech.),
Miura, H.,
Araki, K. (Okayama Univ. of Science),
Tsubokura, M. (Elec. Commun. Univ.)

We investigated on the structures which are responsible for generation of dissipation of the turbulent energy in homogeneous isotropic and shear turbulence. We considered the incompressible case in this fiscal year.

Using the direct numerical simulation (DNS) data, we extracted the dissipative structure. It is shown that its structure is similar to that of the Lundgren stretched-spiral vortex (LSV) 1). Fig. 1 shows a typical example identified in isotropic turbulence at $R_\lambda \sim 77$. The grid resolution of the data was $k_{\max}\eta \sim 4.0$ (Run 1), where $k_{\max}$ denotes the maximum wave number, and η the average Kolmogorov scale. The vortex sheet was identified using the eigenvalue of $[A_{ij}]$, $[A_{ij}]_+$ 2). The heavy dashed line shows the low-pressure region which comprises the core region of the vortex tube. The solid lines display the dissipation rate ε. It is seen that the sheets around the core are stretched to extreme length, and form the spiral turns. Intense dissipation takes place along these stretched sheets.

This LSV is formed not by a conventional rolling-up of a single sheet due to the Kelvin-Holmhelz instability but by accumulation of the low pressure region in the recirculating flow caused by the stagnation flow 3). LSV consists of the three modes of configurations regarding the alignment of the vorticity vectors on the lower sheet (marked L), the upper sheet (U) and the tube. LSV shown in Fig. 1 is in an asymmetric mode. One of two symmetric modes was selectively observed in shear turbulence. This mode and asymmetric mode tended to be converted into the remaining symmetric mode.

Formation of the spiral turns was attributed to the differential rotation incurred by the vortex tube and sheets. The differential rotation was large along the vortex sheet, which induces stretching and thinning of the sheets. Subsequently, intense energy cascade and dissipation occurred along the stretched spiral sheets.

The p.d.f of ε exhibited long tails in large values, and an extraction of this intermittent dissipation field caused by the thinning of the sheet was critically dependent on the grid resolution. Figure 2 shows the fractal dimension of ε, d_ε estimated using the box-counting of the most intense sets defined by thresholding of ε. As $k_{\max}\eta$ is increased, d_ε increases and ~1.8 in Run 1 with small dependence on the threshold value, suggesting the structures in the form of (wrinkled) sheets. Closeness of the fractal dimension of $[A_{ij}]_+$, $d_{[A]+}$, and d_ε indicates that fractal properties of the sheet and dissipation field are similar. These results are consistent with the results obtained using Fig. 1.

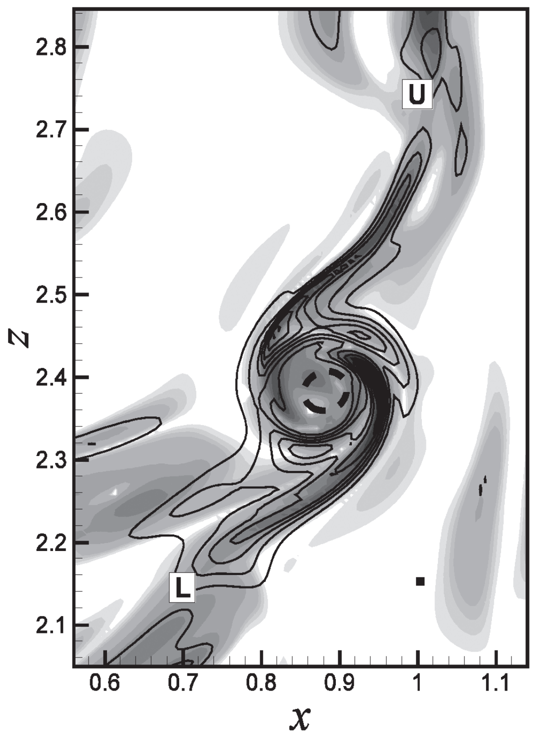

Fig. 1 Isocontours of $[A_{ij}]_+$, ε and p obtained from Run 1

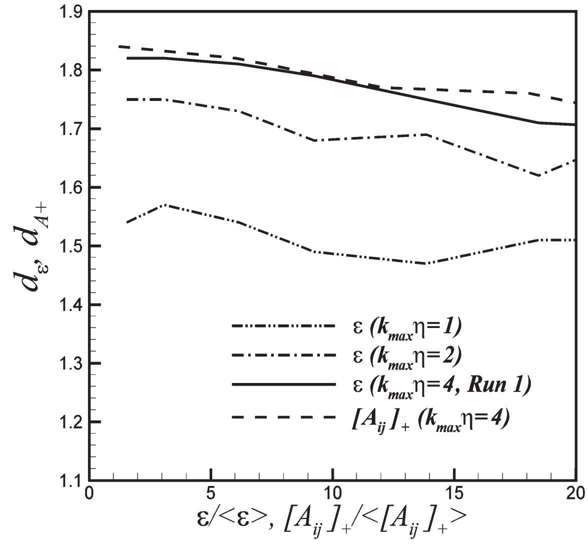

Fig. 2 Threshold value dependence of fractal dimensions of ε and $[A_{ij}]_+$.

Reference

1) Lundgren, T.S., Phys. Fluids **25** (1982) 2193
2) Horiuti, K. and Takagi, Y., Phys. Fluids **17** (2005) 121703
3) Horiuti, K. and Fujisawa, T., submitted to J. Fluid Mech. (2006)