Fundamentals group

The participants in the fundamentals section used numerical simulation results to answer fundamental questions regarding the nature of turbulence. Of the six papers in this section, three are concerned with homogeneous turbulence. Gotoh & Rogallo and Pullin & Rogallo investigated the statistics of the pressure in isotropic turbulence while Chasnov studied the the existence of asymptotic similarity states in decaying axisymmetric turbulence. The other three papers are on a wide range of topics. Verzicco & Shariff report on studies of sound generation by three-dimensional instabilities of vortex rings. Three-dimensional instabilities of stream-wise vortices in channel and Couette flow were investigated by Coughlin, Jiménez & Moser. Finally, simulations of supersonic turbulent boundary layers were studied by Guo & Adams. A brief discussion of these reports follows.

In Pullin & Rogallo, the pressure as well as dissipation and enstrophy spectra obtained from DNS and LES simulations of isotropic turbulence were studied. There was weak evidence of a $k^{-7/3}$ spectrum, as expected from Kolmogorov-like analysis. There was also evidence of an inertial range in the dissipation and enstrophy power spectra. Of key interest here, though, was the Kolmogorov constants for the pressure spectra, which were compared to predictions based on two models of the turbulence statistics, one being based on a joint normal hypothesis, and the other based on the spiral vortex model of Lundgren (1982). The value obtained from the simulations is more than a factor of two higher than the model predictions. However, there are uncertainties in the simulation results for the pressure related to the finite domain size and modest Reynolds number, so these results are not conclusive.

Gotoh & Rogallo also looked at the pressure statistics in isotropic turbulence, but in their case the main interest was in the PDF's and other statistics of pressure and its gradients. Several interesting observations were made. For example, they note that the pressure PDF is highly asymmetric, with an exponential tail for the negative fluctuations. This is consistent with the occurrence of low pressure in the core of intense vortices. Also, the Lagrangian two-time correlations of the pressure gradient has a much smaller time scale than the velocity.

Using large-eddy simulation, Chasnov found that decaying axisymmetric homogeneous turbulence evolves to similarity states, with different states depending on the nature of the initial spectrum. In the similarity state, the spectrum decays self-similarly as a power-law in time. As in isotropic turbulence, the power law exponent depends on the form of the initial spectrum at low wavenumber (i.e. $E(k) \propto k^s$ for $s = 2$ or $s > 2$) Interestingly, Chasnov also found that only for $s > 2$ does the flow relax toward isotropy. When $s = 2$, the low wavenumbers are frozen into the k^2 form and are also frozen into anisotropy.

Instabilities in vortex rings were studied by Verzicco & Shariff, and in particular, they were interested in the sound generated by the evolution of three-dimensional modes on a vortex ring. They successfully simulated a vortex ring undergoing three-dimensional break-down and obtained results consistent with previous observations.

However, the computation of the resulting sound proved more difficult. To compute the sound via the theory of Möhring, moments of the vorticity are computed, and these cause difficulties due to the artificially imposed radial and stream-wise (periodic) boundary conditions. The authors were not able to obtain a result that was independent of the size of the integration domain for computing the moments.

The work by Coughlin *et al.* was based on the speculation that the evolution of three-dimensional instabilities in the near-wall region of a turbulent flow may be similar to the instabilities of the vortices in Taylor-Couette flow. This is studied by applying an analysis similar to that of Coughlin & Marcus to the minimal channel and the minimal Couette flow. The stream-wise vortices in these flows are considered to be quasi-steady since they decay very slowly, and instabilities growing with these vortices as a base-flow are investigated. It is found that these vortices are indeed unstable to three-dimensional disturbances on a time scale much shorter than the decay of the vortices, suggesting that this instability is responsible for the growth of turbulence in the minimal flows. It would be interesting if these results could be applied to a full-scale turbulent wall-bounded flow.

In Guo & Adams, direct numerical simulations of compressible boundary layers with Mach number up to 6 were attempted. A parallel flow approximation similar to that used by Spalart for incompressible boundary layers was used. In this work the numerical simulations were actually done elsewhere (at DLR in Germany) and the data was brought for analysis during the summer program. During the course of the analysis, it became clear that the high Mach number flows suffered from too small a computational domain. This was caused by the hot wall (adiabatic in the mean) boundary conditions which cause the viscosity to increase markedly near the wall. This resulted in streaks with stream-wise and span-wise sizes that were too large for the computational domain. In these cases the turbulence length scales are much larger near the wall than away from the wall, which is the opposite problem from incompressible flows.

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