Effects of sharp vorticity gradients in two-dimensional hydrodynamic turbulence

The appearance of sharp vorticity gradients in two-dimensional hydrodynamic turbulence and their influence on the turbulent spectra are considered. We have developed the analog of the vortex line representation as a transformation to the curvilinear system of coordinates moving together with the divorticity lines. Compressibility of this mapping can be considered as the main reason for the formation of the sharp vorticity gradients at high Reynolds numbers. For two-dimensional turbulence in the case of strong anisotropy the sharp vorticity gradients can generate spectra which fall off as \( k^{-3} \) at large \( k \), resembling the Kraichnan spectrum for the enstrophy cascade. For turbulence with weak anisotropy the \( k \) dependence of the spectrum due to the sharp gradients coincides with the Saffman spectrum, \( E(k) \sim k^{-4} \). We have compared the analytical predictions with direct numerical solutions of the two-dimensional Euler equation for decaying turbulence. We observe that the divorticity is reaching very high values and is distributed locally in space along piecewise straight lines, thus indicating strong anisotropy, and accordingly we find a spectrum close to the \( k^{-3} \) spectrum. ©2007 American Institute of Physics