Lee, Joung-Ho; **Sung, Hyung Jin**

Structures in turbulent boundary layers subjected to adverse pressure gradients. (English)

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Summary: The effects of adverse pressure gradients on turbulent structures were investigated by carrying out direct numerical simulations of turbulent boundary layers subjected to adverse and zero pressure gradients. The equilibrium adverse pressure gradient flows were established by using a power law free-stream distribution $U_\infty \sim x^m$. Two-point correlations of velocity fluctuations were used to show that the spanwise spacing between near-wall streaks is affected significantly by a strong adverse pressure gradient. Low-momentum regions are dominant in the middle of the boundary layer as well as in the log layer. Linear stochastic estimation was used to provide evidence for the presence of low-momentum regions and to determine their statistical properties. The mean width of such large-scale structures is closely associated with the size of the hairpin-like vortices in the outer layer. The conditionally averaged flow fields around events producing Reynolds stress show that hairpin-like vortices are the structures associated with the production of outer turbulence. The shapes of the vortices beyond the log layer were found to be similar when their length scales were normalized according to the boundary layer thickness. Estimates of the conditionally averaged velocity fields associated with the spanwise vortical motion were obtained by using linear stochastic estimation. These results confirm that the outer region of the adverse pressure gradient boundary layer is populated with streamwise-aligned vortex organizations, which are similar to those of the vortex packet model proposed by Adrian, Meinhart & Tomkins (J. Fluid Mech., vol. 422, 2000, pp. 1-54). The adverse pressure gradient augments the inclination angles of the packets and the mean streamwise spacing of the vortex heads in the packets.

MSC:

76F40 Turbulent boundary layers

Full Text: DOI

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