A comparative study of artificial and natural streamwise vortices in the near-wall region of turbulent boundary layers

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A low-friction-Reynolds-number ($Re_\tau \approx 400 - 480$) turbulent boundary layer (TBL) perturbed by additional streamwise vortices is investigated using well-resolved Large Eddy Simulation (LES)[1]. To better understand how one might passively mimic and/or manipulate the formation of streamwise vortex pairs (SVPs) that naturally occur as part of the near-wall cycle[2], SVPs are artificially produced by *small* vortex generators (of height $h^+ = 30$) within the near-wall region of a TBL. Present study contrasts the usual *large* vortex generators used in TBL manipulation. The instantaneous streamwise fluctuation velocity fields show comparable magnitude between artificial and natural streamwise vortices in the near-wall region of the TBL. Analyses employing a triple decomposition[3] of velocity and pressure and its extension to the incompressible Navier-Stokes equation is used to better understand the coherent and turbulent fields associated with both the artificial and naturally occurring SVPs. Overall, it is observed that the artificial and natural streamwise vortices have similar interaction with the surrounding turbulent field, and exhibit striking similarities in statistical structure. In particular, it is found that the artificial SVPs exhibit a remarkably similar signature of kinetic energy transport with their counterparts in a natural TBL. This suggests that the wall-response to SVPs may in fact constitute a generic mechanism underlying turbulent transport near the wall. These and other similarities may augment, attenuate or otherwise manipulate wall turbulence by supplying artificial streamwise vortices in near-wall region.

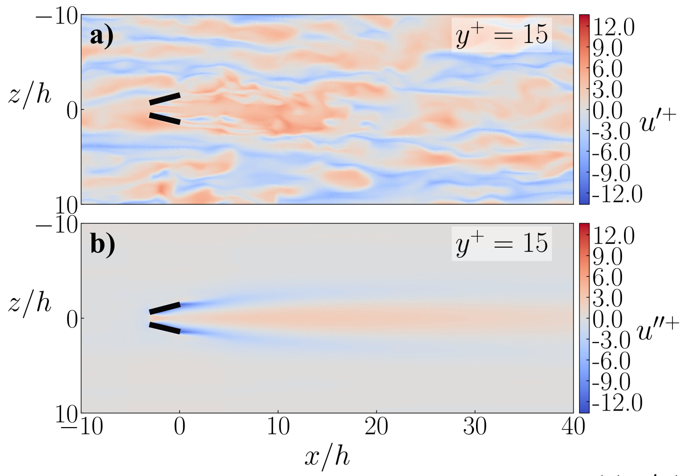

Figure 1: The plan view of streamwise fluctuation velocity field: (a) u' (turbulent), (b) u'' (coherent) induced by artificial streamwise vortices at $y^+ = 15$. Both u' and u'' are of comparable magnitude.

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[1]Meinke, et al., *Comput. Fluids* **31**, 695 (2002).
[2]Waleffe and Kim, *Self-Sustaining Mechanisms of Wall Turbulence*, Southampton (1997).
[3]Chan et al., *J. Fluid Mech.* **854**, 5 (2009).