Effects of large-eddy break-up device on skin friction drag reduction at various wall-normal locations

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A paradigm shift in the understanding of wall turbulence took place once a certain degree of order was found to exist in the larger eddies of turbulent flows[1]. Coherent motions have been found to play a major role in the growth and evolution of turbulent boundary layers, thereby opening doors for the beneficial manipulation and control[2]. A well-resolved large eddy simulation (LES) of a large-eddy break-up (LEBU) device in a spatially evolving turbulent boundary layer is performed with, Reynolds number, based on free-stream velocity and momentum thickness, of $Re_\theta \approx 4300$ at two wall normal locations $y \approx 0.1\delta$ & 0.8δ (δ denoting the local boundary layer thickness at the location of the LEBU). Figures 1(a,b) show the instantaneous flow field in the vicinity of the LEBU at (a) $y = 0.1\delta$ and (b) $y = 0.8\delta$ respectively. The wake effect from the LEBU at $y \approx 0.8\delta$ within the boundary layer is clearly more evident. The corresponding skin friction coefficient c_f is compared to a turbulent boundary layer without LEBU (figure 1(c,d)). The c_f for the LEBU at $y \approx 0.1\delta$ seems to converge back to that a turbulent boundary layer (without LEBU) after $x/\delta_o^\star \approx 1000$ after the LEBU. The c_f for the LEBU at $y \approx 0.8\delta$ clearly extend far beyond that. The current results seem to indicate that influencing the outer region of the turbulent boundary layer results in a more substantial skin friction drag reduction.

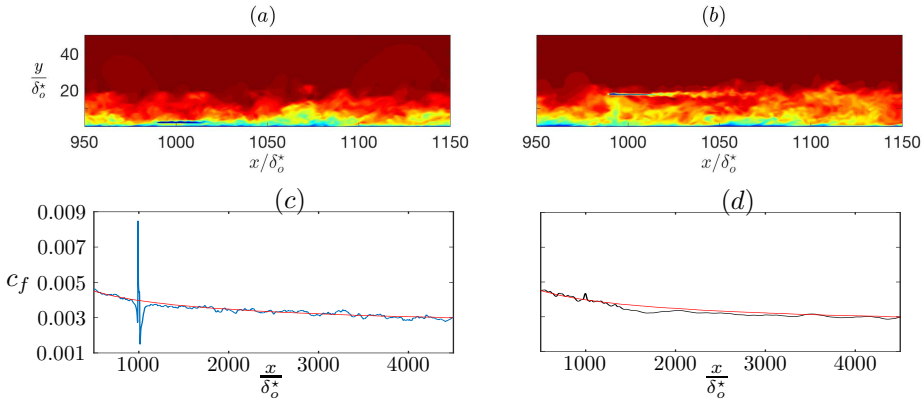

Figure 1: (a,b) shows the instantaneous streamwise velocity in the vicinity of the LEBU at wall normal location of $y = 0.1\delta$ & 0.8δ respectively. Red indicates high velocity and blue is low velocity. (c,d) exhibits the skin friction coefficient for $y = 0.1\delta$ & 0.8δ respectively. Red line denoted the c_f for a turbulent boundary layer without any LEBU; Blue line is for c_f at $y = 0.1\delta$ and black line is for c_f at $y = 0.8\delta$.

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[1]Townsend, *The Structure of Turbulent Shear Flow*, Cambridge University Press (1956).
[2]Corke et al., *Tech. Rep. 3444, NASA CR*, 54 (1981).