Direct numerical simulations of turbulent flows over the converging and diverging riblets

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Different from streamwise-aligned riblets, the converging and diverging riblets (C-D riblets)[1] are arranged obliquely along the main flow direction, designed to create a large-scale secondary flow[2] that mudulates or controls the existing large-scale vortical structures in wall turbulence and significantly alters the turbulence statistics from the near-wall region to the outer layer. In this study, we perform direct numerical simulations of turbulent flow over the C-D riblets at a friction Reynolds number $Re_\tau = 180$. Although the Reynolds number is low, the changes on aerodynamic forces, turbulence statistics and coherent structures, mostly associated with the spanwise periodicity of the wall surface, may give us more insights and promote the further development of this drag-reduction approach. Based on the DNS data, we find that compared to the smooth-wall case, the C-D riblets are capable to reduce the skin-friction drag, but they will increase the pressure drag in the diverging region, by an amount to result in a larger total drag. Details of the time-averaged flow-fields are presented to assess the specific flow features in the presence of C-D riblets. Significant modifications in the distributions of Reynolds stresses and turbulence kinetic energy are also observed. Furthermore, observations of instantaneous velocity fields, the vortical structures and auto-correlations of the streamwise velocity reveal modified and rearranged turbulence structures.

Figures 1(a) and (b) clearly show that the profiles of the local integrated streamwise wall-shear stress (Γ_x) and the pressure drag (D_p) in the spanwise direction, respectively. Compared to the baseline case, it implies that Γ_x is increased near the DL ($z/\Lambda = 0$), and reduced as it approaches the CL ($z/\Lambda = 0.5$). Figures 1(b) shows D_p in the baseline case is zero, but in the C-D riblets case, D_p near the DL is pretty large.

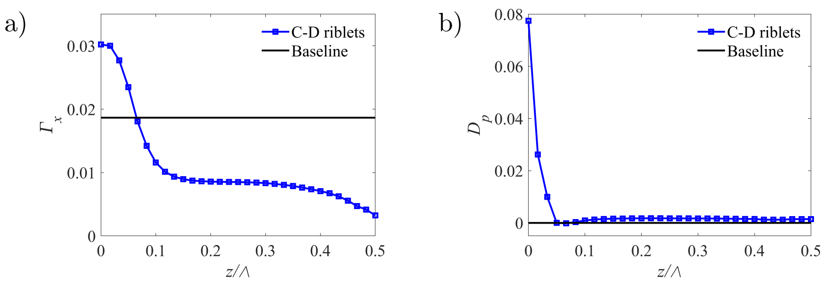

Figure 1: Profiles of (a) the local integrated streamwise wall-shear stress (Γ_x) and (b) the pressure drag (D_p) in the spanwise direction.

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[1] Koeltzsch et al., *Exp. Fluids* **33**, 346–350 (2002).

[2] Nugroho et al., *Int. J. Heat Fluid Flow* **41**, 90–102 (2013).