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Coupling between roughness and freestream acceleration in turbulent boundary layers JUNLIN YUAN, UGO PIOMELLI, Queen's University — To explain various rough-wall flow responses to different types of free-stream conditions previously observed, we carried out a direct numerical simulation of a spatially developing turbulent boundary layer with freestream acceleration. Unlike the equilibrium (self-similar) accelerating scenario, where a strong acceleration leads to complete laminarization and lower friction, in the present non-equilibrium case the friction coefficient increases with acceleration, due to the faster near-wall acceleration than that of the freestream. At the same time, roughness reduces the near-wall time scale of the turbulence, preventing the acceleration from linearly stretching the near-wall eddies and freezing the turbulence intensity as in the smooth case. In addition, acceleration leads to similar decrease of mean-velocity logarithmic slope on rough and smooth walls; this allows a clear definition of the roughness function in a local sense. Interestingly, this roughness function correlates with the roughness Reynolds number in the same way as in self-similar or non-accelerating flows. This study may also help develop benchmark cases for evaluating rough-wall treatments for industrial turbulence models.

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