Investigation of turbulent flows over regular roughness in the limit of low planform and frontal solidity

A. Busse*, O. Zhdanov*

Dating back to the work by Schlichting[1], fundamental investigations of turbulence over rough surfaces often consider surfaces constructed by placing roughness elements in regular patterns. Two key parameters are known to govern the behaviour of such surfaces: the planform solidity, λ_p, i.e., the fraction of the wall covered by roughness elements, and the frontal solidity, λ_f, i.e., the projected frontal area of the roughness elements per unit planform area. The most widely studied type of roughness element is the cube. However, surfaces roughened by placement of uniformly sized cubes have the property that planform and frontal solidity are linearly proportional to each other. By using other roughness elements shapes, such as cones or pyramids[2] independent variation of planform and frontal solidity is possible. Pyramids with a square base have the additional advantage over cones or cubes that a planform solidity of 1 can be achieved.

The aim of the current study is to explore the low roughness limit, i.e., where frontal and/or planform solidity approach zero, using pyramid-shaped roughness elements with a square base. To this end, direct numerical simulations of turbulent channel flow at $Re_\tau = 395$ are currently in progress for a series of surfaces where the planform solidity is varied between 0.11 and 1 and the frontal solidity between 0.025 to 0.1. Preliminary results show that the rough-wall turbulence approaches the rough-smooth limit in different ways depending on whether λ_p is decreased while λ_f is kept constant and vice versa. For example, strong large-scale secondary currents only emerge in the limit of λ_f approaching zero while λ_p is kept to a constant value. A detailed comparison of the influence of λ_f and λ_p effects will be made covering mean flow and turbulence statistics as well as the structure of the flow.

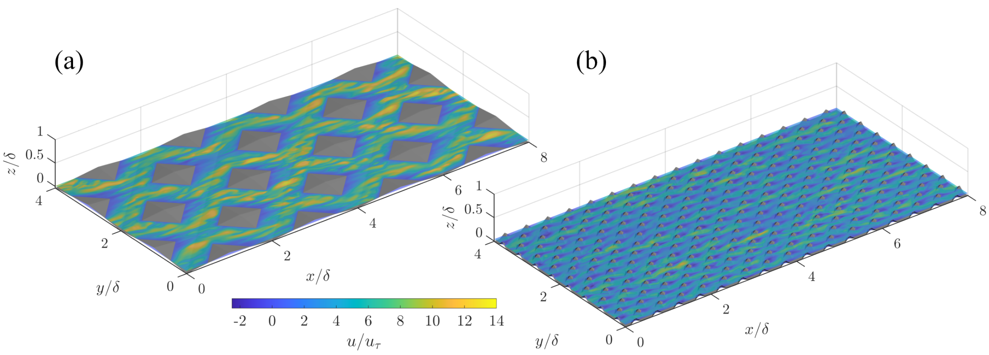

Figure 1: Instantaneous streamwise velocity field in a horizontal plane at pyramid half-height for cases (a) $\lambda_f = 0.05$, $\lambda_p = 1$, and (b) $\lambda_f = 0.1$, $\lambda_p = 0.25$.

*James Watt School of Engineering, University of Glasgow, Glasgow, United Kingdom

[1]Schlichting, *Ingenieur Archiv* **7**, 1-36 (1936).

[2]Schultz and Flack, *Physics of Fluids* **21**, 015104 (2009).