NUMERICAL STUDY OF ROUGH SURFACES IN WALL BOUNDED FLOWS

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ABSTRACT

Direct numerical simulation (DNS) of a turbulent channel flow with wedges of random height on the lower wall have been performed. Two other simulations have been carried out to assess the effect of the geometry on the overlying flow. One considers the flow over the same surface but removing the smallest elements, the other has a uniform distribution of wedges such that the longitudinal area is the same of that corresponding to the random elements. Roughness is treated by the immersed boundary method.

Results show that the pressure distribution $P(x)$ on the frontal faces raises slightly when the smallest wedges are removed (except when these are shielded by the largest ones). The increase of $P(x)$ raises drastically when the removed wedge is a bit higher. Also, flow reattachment to the smooth wall and a slight decrease of the skin friction coefficient, $C_f(x)$, is obtained in most of the cases.

For the uniformly distributed wedges, larger recirculation regions increase the pressure drag and make the mean flow slower inside the roughness sublayer, $y/h \leq -0.8$. In general pressure drag represents the main effect on the friction velocity u_τ. Also, higher values of the Reynolds shear stress $-\langle uv \rangle$ and its gradient as well as a higher increase of the RMS-velocity fluctuations u, v, and w (until $y/h \approx 0.5$), and less distortion beyond the roughness sublayer are obtained. A one-dimensional spectral analysis of velocity and pressure reproduces the highest peak density value at a wavelength equal to the periodic wedges-spacing.

On the other hand, the theory by George and Castillo (1997) is extended for rough surfaces and numerically implemented to obtain a solution of the Reynolds shear stress, $-\langle uv \rangle$, on zero pressure gradient (ZPG) turbulent boundary layers. The method is based on similarity transformations of the Navier-Stokes equations, over the entire domain. The solution is in good agreement with the experiments in the inner and outer regions, for hydraulically smooth and transitionally rough surfaces up to a roughness parameter $k^+ \approx 55$. Beyond this limit, accuracy decreases drastically with k^+. However, it always increases with the Reynolds number, Re_θ. The friction power law for rough surfaces has been used for all calculations and comparisons with direct methods and velocity based methods are shown.