Direct Numerical Simulations of a Flow over Rough Walls

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Abstract:

Turbulent flows over rough surfaces are often encountered in practice; in the atmosphere, the underlying surface is usually rough, while, in an engineering context, pipes and ducts cannot be regarded as hydraulically smooth, especially at high Reynolds numbers. Rough surfaces may be used to enhance heat transfer, albeit at the expense of increasing the drag; alternately, the roughness geometry may be selected so as to decrease the drag, e.g. by using riblets, or delay transition. Since the roughness can seriously degrade the performance of airfoils, wings and turbomachinery blades, the ability to predict its effect is important.

A direct numerical simulation technique, using an immersed boundary method for the obstacles, was employed with typically 50 million cells. It is shown that the surface drag is predominantly form drag, which is greatest at an area coverage around 15%. Frictional and form drag present a similar dependence with the roughness density. Two-point velocity correlations, with the fixed point at several locations within one roughness wavelength show a decreased coherence in the streamwise direction with respect to a smooth wall. On the other hand, the coherence in the wall normal direction has increased. The departure from isotropy of the Reynolds stress tensor is also examined in the context of its anisotropy invariants (Leonardi et al. 2004). The flow is more isotropic over a rough wall. We also consider the effect roughness has on the way the cavity communicates with the overlying flow. Passive scalar and energy equations have been solved. Results show an increased mixing and heat transfer over rough walls. The roughness density maximizing the heat transfer is in about 10%. A new parametrization of the roughness geometry will be discussed. In fact there is no satisfactory correlation between the roughness function and parameters describing the roughness geometry. It will be shown at the seminar that a satisfactory collapse of the data is achieved when the roughness function is plotted against the $rms$ wall–normal velocity averaged over the plane of the roughness crests (Orlandi & Leonardi 2008).

Biography:

Stefano Leonardi got a Master degree in Aeronautical Engineering (1999) and a PhD in Theoretical and Applied Mechanics (2002) at the University of Rome "La Sapienza", Italy. He was a Postdoctoral Fellow up to 2006 during which he had research visitor appointments at the University of Newcastle Australia, University of Southampton, Centre of Excellence for Computational Mechanics Politecnico Bari, Institute of Oceanography SCRIPPS San Diego and University of Washington, Seattle.

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.