Linear aspects of the turbulent flow response to general roughness

Miles Chan[1], Ugo Piomelli[2], Beverley McKeon[3]
[1]Graduate Aerospace Laboratories at the California Institute of Technology
[2]Department of Mechanical and Materials Engineering at Queen's University
[3]Center for Turbulence Research at Stanford University

At sufficiently high Reynolds numbers, all surfaces are hydrodynamically rough. While the drag penalty of different surfaces (sandgrain, biofouled, painted, etc.) can be characterized by statistical parameters of the surfaces, a general relationship between the flow response and arbitrary surfaces remains unknown [1]. Recently, temporally- and spatially- resolved data has become available, allowing researchers to demonstrate that the spatial variation of the time-averaged flow is strongly correlated with the roughness geometry [2]. Experiments conducted on the flow over singly-periodic roughness suggest that the linear response of the velocity Fourier modes corresponding to the periodic roughness is significant [3].

This work characterizes the temporally-averaged, spatially-resolved velocity and Reynolds stresses obtained from DNS of a channel with sandgrain roughness [4]. The broadband nature of the sandgrain roughness provides an opportunity to evaluate the linearity of the response to the most important Fourier modes of the roughness and connections to the observed physics of rough wall flows. The trends identified in the data are discussed and their usefulness for modeling global flow quantities such as the dispersive Reynolds stress and the drag are evaluated.

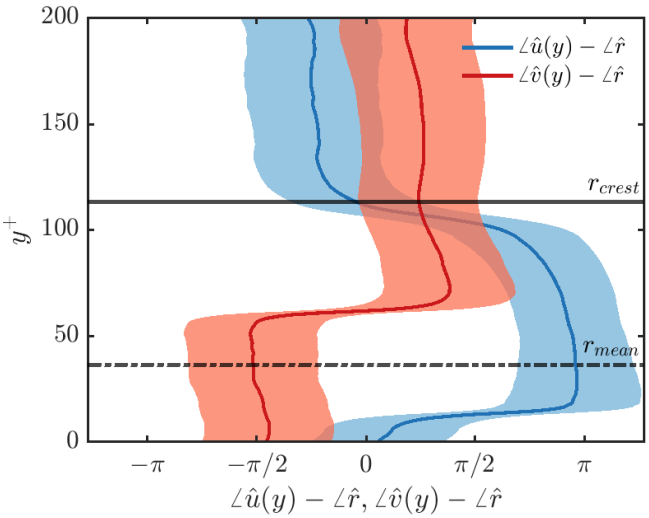

Figure 1: Relative phase of the velocity Fourier modes $\hat{u}$, $\hat{v}$ with respect to the roughness Fourier modes $\hat{r}$ (considering 4% of roughness modes with highest amplitude). The average is plotted as a solid line, while the band width is 2x the standard deviation.

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References

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