Characteristics of Turbulent Boundary Layers Over Heterogeneous Roughness

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While, it is commonly known that biofouling contributes to enormous drag penalties on hydrodynamic surfaces [1], dry-docking and in-water cleanings largely rely on visual inspections of the surface conditions, and the intermittent cleanings can hamper a mission timeline. Thus, there is a need to relate qualitative surveys of ship hull conditions to quantitative specifications of the performance penalty. The present work aims to expand the current database of rough wall boundary layer flows by providing descriptions of the mean turbulence statistics and hydraulic parameters for a variety of heterogeneous rough surfaces.

The roughness in this study is designed based on randomized individual organisms (i.e. tubeworms and barnacles) which resemble typical biofouling topographies found on naval ship hulls. Experiments are conducted in a water tunnel [2] in zero-pressure-gradient configuration, and profiles of mean velocity and turbulence quantities (such as those shown in Figure 1) are measured using laser Doppler velocimetry (LDV). These measurements are compared to direct numerical simulations (DNS) over spatially developing boundary layers employing the same topographical arrangements. The latter are conducted utilizing an in-house finite-difference Navier-Stokes solver for incompressible flows. A structured Cartesian grid coupled with an immersed boundary method (IBM)[3] is used to directly resolve the roughness. The final presentation will show additional streamwise and spanwise evolutions of the turbulence statistics across four wall conditions and provide comparison between the experimental and computational results.

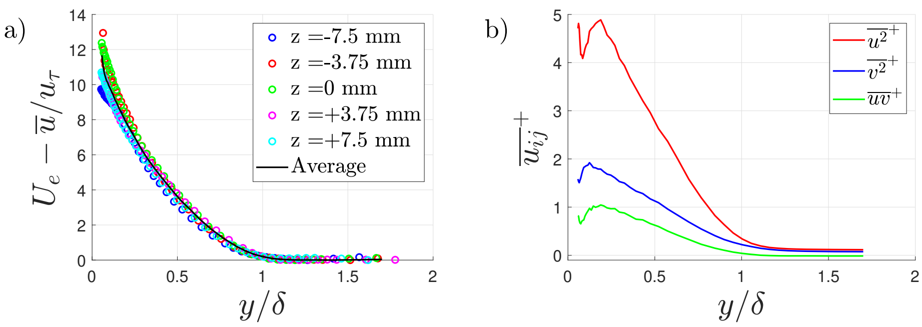

Figure 1: Mean statistics from LDV measurements of the turbulent boundary layer over tubeworm roughness. (a) Spanwise variations of the mean velocity defect. (b) Spanwise averaged Reynolds stress profiles.

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