On the effect of superhydrophobic surfaces in turbulent channel flow

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From experimental and numerical investigations it is known that superhydrophobic surfaces lead to a decrease in skin friction drag in laminar and turbulent channel flow [2]. For turbulent channel flow, a drag reduction up to 50% can be achieved. This reduction in skin friction drag is achieved by providing an alternating gas-liquid solid-liquid interface that results in an alternating no-slip no-shear boundary condition. For laminar flow an analytic solution for calculating the effective slip length in the Stokes limit exists for certain geometries, namely for ribs oriented parallel and perpendicular to the flow [3]. The effective slip length is a parameter for quantifying the benefit of a superhydrophobic surface. For turbulent flow, no analytic solution or correlation functions are available.

Within the present investigation, the impact of a superhydrophobic surface pattern oriented parallel to the main flow direction on turbulent channel flow is shown using direct numerical simulation (DNS). The predictions are carried out with a constant pressure gradient, respectively $u_\tau = const.$ The friction Reynolds number is chosen to be $Re_\tau = 180$. It is shown, that for short-wave surface structures, the effective slip length in turbulent channel flow is in good agreement to the corresponding Stokes solution. However, for an increase in the wave-length of the alternating boundary conditions a deviation in effective slip length occurs. In order to identify the mechanism responsible for the observed phenomenon, the FIK-Identity [1] is used. In doing so, the resulting bulk mean velocity can be decomposed into a slip contribution, a laminar contribution and a turbulent contribution. Special attention is given to the influence of the modified surface on the turbulent quantities. In addition a critical assessment of the potential benefit of using superhydrophobic surfaces in laminar and turbulent channel flows is presented.

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