In search of an optimal surface: drag predictions of rough surfaces from boundary layer models

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Abstract

We are interested in passive turbulent flow control by manipulating the boundary layer of turbulent flow using tiny microstructures. Direct Numerical Simulations (DNS) of fully developed turbulent flows are very time consuming if one would like to resolve both: the turbulence and the microstructures. With the combination of modeling, anlysis and numerical simulations, we aim a contribution in reducing the computation times for accurate drag predictions from a near-wall model.

We will present models for the viscous sublayer and for the buffer layer of turbulent flows above rough surfaces. The model equations are described by the Navier-Stokes system. For the case of the viscous sublayer when the sturctures are very small, the existence of a solution for general microstructures was shown in [6]. The homogenization theory could then be applied to derive the limit system for vanishing microstructures and the drag can be replaced with the so-called effective drag on a smooth surface which is easier to compute. For a specified microstructure the effective drag is evaluated on an artificial smooth surface fixed above the structures [4], [3]. The position of this artificial smooth surface and as well as the position of the respective smooth wall is very important for drag evaluations and comparison from our near-wall models. Using the homogenization theory we will provide drag predictions with an accuracy per mill [7] based on numerical simulations using Finite Elements. We use biquadratic Finite Elements together with a stabilization technique developed in R. Rannacher's group [1] and methods based on error control and mesh adaption [2], [8]. In this framework a shape optimization problem was solved [3] to figure out the optimal structure and to explain the drag reducing mechanism of riblets known from shark skin.

References

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