# Flow Control of Near-Wall Turbulence

# Strömungskontrolle wandnaher Turbulenz

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Berichte aus der Strömungstechnik

**Bettina Maria Frohnapfel**

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# Abstract

The present work aims at providing further understanding of the mechanism of turbulent drag reduction (DR). Based on analytical considerations about how turbulence needs to be modified in order to reduce the momentum loss towards solid walls and to yield lower energy losses, a mechanism of turbulent DR is proposed. This mechanism suggests that drag reducing flow control at high Reynolds numbers should be designed to minimize the turbulent dissipation rate at the wall. A review and analysis of existing DNS databases for which DR has been reported shows that the proposed DR mechanism is commonly found. Based on the obtained knowledge a tentative surface structure with grooves aligned in the flow direction is suggested for flow control of near-wall turbulence. A hydraulic model is presented that allows an estimate of the expected wall shear stress reduction which can be converted to DR.

The grooved surface structure is tested both numerically (in collaboration with Dr. Peter Lammers from HLRS Stuttgart) and experimentally. The numerical simulations are carried out for grooves which scale with the thickness of the viscous sublayer. The results obtained show significant DR - based on the wall shear stress reduction - and are in excellent agreement with the hydraulic model predictions. Experimentally, the pressure drop in a channel with grooved surfaces is compared with the one in a smooth channel. It is found that a significant reduction in pressure drop is only obtained for grooves in the order of one viscous length scale, which corresponds to half the Kolmogorov scale. The careful analysis of these results reveals that wall shear stress and pressure drop might lead to different findings when extremely small secondary motions are involved.

Based on the presented analysis it is concluded that drag-reducing techniques that are to be applied at high Reynolds number should be designed to minimize the turbulent dissipation rate at the wall but also to minimize secondary motion. Furthermore, the results obtained suggest that testing of DR techniques has to be done with great care when spanwise variations are involved. The reason for that is the possible appearance of secondary motions which might (partially) consume what is gained by wall shear stress reduction. Finally, the present work shows that flow control does not necessarily have to focus on large-scale coherent structures, as most current research efforts do, but can be achieved by influencing the smallest scales of the turbulent motion.

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