A study of drag reduction on rough walls using spanwise opposed wall-jet forcing

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Friction between flowing fluids and solid surfaces is one of the main sources of energy loss in engineering applications. In most of these applications, solid walls in contact with the flowing fluids are significantly rough. Considering the maritime industry, roughness of ship hulls (e.g. as a result of bio-fouling) is a significant factor affecting the energy efficiency of the ships. This motivates studying the feasibility, and efficiency of different flow control methods on rough walls.

This study analyzes the drag control response of spanwise opposed wall-jet forcing (SOJF) introduced by Yao et al.[1] to the presence of surface roughness. Using this method, the key questions are whether or not turbulent motion can be suppressed near a rough wall, whether drag reduction can be achieved at the same actuation parameters as on a smooth wall, and whether or not the method is energy-efficient for rough walls. To this end, DNSs (using a pseudo-spectral incompressible Navier–Stokes solver SIMSON[2]) are carried out to compare the amount of drag reduction and required input power in smooth and rough channels at the friction Reynolds number of Re_τ=180.

It is shown that the maximum drag reduction in a rough channel is achieved at a larger forcing amplitude A^+ than in a smooth channel. Moreover, the maximum achieved drag reduction value in the rough channel (2.4% at $A^+ = 0.035$) was found to be meaningfully smaller than that of the smooth channel (18.6% at $A^+ = 0.015$). Figure 1(a,b) visualizes the near wall streaks of normalized total turbulent fluctuation (u'^+) for optimally controlled smooth and rough channels, respectively, at $y^+ = 20$. Although the spanwise jets partly merge the streaks together in a rough channel, the effect is much less pronounced than in the optimal smooth case. It was moreover found that the method may not be energy-efficient for rough walls pointing towards further investigations.

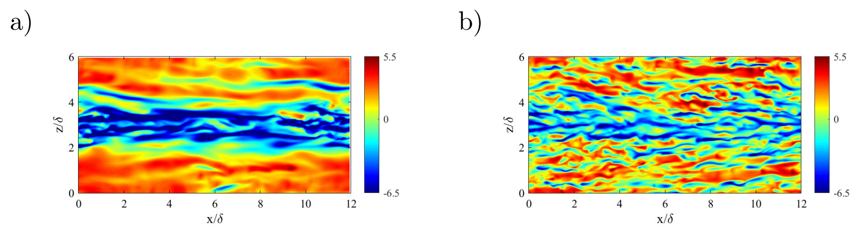

Figure 1: Contours of normalized total streamwise velocity fluctuations (u'^+) in the horizontal (x-z) plane at $y^+ = 20$ for optimally controlled (a) smooth, and (b) rough channels.

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[1] Yao et al., *J. Fluid Mech.* **852**, 678–709 (2018).

[2] Chevalier et al., Technical Report No. TRITAMEK KTH Mechanics, Stockholm, Sweden (2007).