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Critical assessment of turbulent drag reduction through spanwise wall oscillations. (English)

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Summary: Direct numerical simulations of the incompressible Navier–Stokes equations are employed to study the turbulent wall-shear stress in a turbulent channel flow forced by lateral sinusoidal oscillations of the walls. The objective is to produce a documented database of numerically computed friction reductions. To this aim, the particular numerical requirements for such simulations, owing for example to the time-varying direction of the skin-friction vector, are considered and appropriately accounted for.

A detailed analysis of the dependence of drag reduction on the oscillatory parameters allows us to address conflicting results hitherto reported in the literature. At the Reynolds number of the present simulations, we compute a maximum drag reduction of 44.7%, and we assess the possibility for the power saved to be higher than the power spent for the movement of the walls (when mechanical losses are neglected). A maximum net energy saving of 7.3% is computed.

Furthermore, the scaling of the amount of drag reduction is addressed. A parameter, which depends on both the maximum wall velocity and the period of the oscillation, is found to be linearly related to drag reduction, as long as the half-period of the oscillation is shorter than a typical lifetime of the turbulent near-wall structures. For longer periods of oscillation, the scaling parameter predicts that drag reduction will decrease to zero more slowly than the numerical data. The same parameter also describes well the optimum period of oscillation for fixed maximum wall displacement, which is smaller than the optimum period for fixed maximum wall velocity, and depends on the maximum displacement itself.

MSC:

76F70 Control of turbulent flows
76M22 Spectral methods applied to problems in fluid mechanics
76M20 Finite difference methods applied to problems in fluid mechanics

Full Text: DOI