Drag reduction effects in a turbulent channel flow induced by spanwise wall oscillations

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We have conducted direct numerical simulations to investigate a turbulent channel flow with sinusoidal spanwise wall oscillations. The linear relation between the drag reduction and a scaling parameter[1,2], related to the oscillating Stokes layer acting on the near-wall turbulence, is exploited for gaining insight into the drag reduction characteristics of the flow.

For a fixed maximum wall velocity W, this parameter is proportional to the maximum streamwise vorticity of the oscillating spanwise layer at a critical distance from the wall between the quasi-streamwise vortices and the low-speed streaks. This finding illustrates the idea that drag reduction is achieved when an efficient shearing motion is imposed onto these coherent structures. The relevance of the Stokes layer on the disruption of the self-sustaining turbulence-producing cycle is thus highlighted.

The difference between the periods of oscillation T which guarantee the maximum drag reduction for a given maximum wall displacement and for a maximum W is outlined for the first time. The scaling parameter is used to determine the net energy saving (see figure 1), computed by taking into account the power spent to move the walls, and very good agreement is found with our highly-accurate DNS results. The dependence of the drag reduction on the Reynolds number is investigated and the drag reduction data in the literature are compared with the prediction given by the scaling parameter, thus attaining a comprehensive view of the state of the art.

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[1] Choi et al., *AIAA J.* **40** (5), 842 (2002).
[2] P. Ricco, M. Quadrio, *J. Fluid Mech.* **521**, 251 (2004).

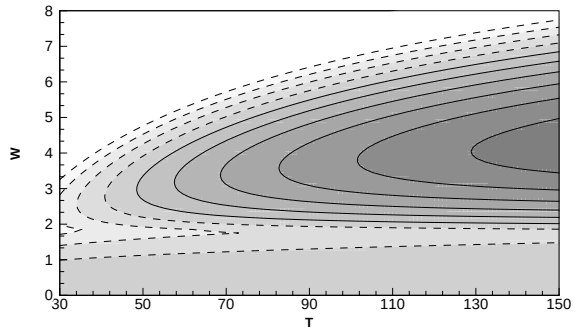

Figure 1: Contours of the percent net energy saving as function of W and T, scaled by inner viscous units of the fixed-wall case. Darker colours indicate a higher net energy saving, contour increments are by 1% and dashed lines are for negative values (only values for $P_{net} \geq -4\%$ are shown).