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On-off pumping for drag reduction in a turbulent channel flow

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Flows alternating between laminar and turbulent regimes are often encountered in nature and in industrial applications. Their understanding has progressed significantly in recent years[1,2], but is still incomplete. In particular, a brief and intense acceleration followed by a longer period of decay is a pattern that, once periodically applied, may lead to a reduction of turbulent friction drag[3]. Indeed, the way power is injected over time to a pumping system to maximize performance is one of the least considered (yet one of the simplest) approaches to flow control.

In this DNS-based work, a turbulent channel flow is driven by pulsed pumping. The periodic forcing is described by the length of the duty-cycle and the duration of the period (see inset in fig.1(a)). The study is computationally demanding due to the strong temporal variation of the flow rate. Since the very concept of drag reduction becomes elusive in a context where the reference is unclear, a proper metric is introduced to assess the performance of the on-off forcing.

The outcome of our study is twofold. First, a portion of the parameter space is investigated, unequivocally demonstrating the ability of the forcing to yield significant savings.

Second, it is found that these savings can be ascribed to the alternation of a quasi-laminar and a fully turbulent state. The random transition among them is marked by a knee in the temporal development of the bulk velocity (point B in fig.1(a)). A partial re-laminarization is attained at the end of the acceleration phase (point A in fig.1(a)). Between A and B, the flow dynamics is dominated by intense anomalous streaks, fig.1(b), whose instability and sudden breakup leads to turbulence. The ability to control their lifetime and intensity is essential to achieve successful control.

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[1] He et al., *Int. J. Heat Fluid Flow* **57**, 130 (2016).

[2] Kern et al., *J. Fluid Mech.* **927**, A6 (2021).

[3] Kobayashi et al., *Int. J. Heat Fluid Flow* **88**, 108783 (2021).

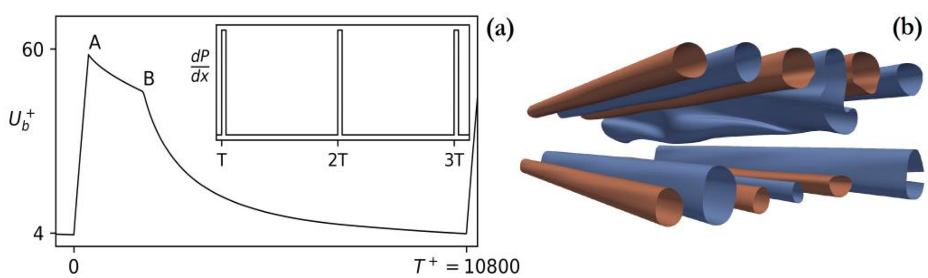

Figure 1: (a) Pressure gradient (inset) and bulk velocity during one forcing period. (b) Positive (red) and negative (blue) contours of the streamwise velocity fluctuations among A and B.