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Active feedback control achieving sub-laminar skin friction drag

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Abstract

Effects of an idealized feedback control are studied by means of direct numerical simulation (DNS). The control input is a body force directly suppressing the Reynolds shear stress near the wall. Namely, the body force is applied in the wall-normal direction and in phase with the streamwise velocity fluctuation. The DNS of turbulent pipe flow at constant flow rate at $Re_b = 5300$ (i.e, $Re_\tau \simeq 180$ for uncontrolled flow) shows that the skin friction can be reduced even to a sub-laminar level. This is caused by the reversal of the sign of Reynolds shear stress, which results in a negative value of "the turbulent contribution to skin friction" [Fukagata et al., *Phys. Fluids* **14**, L73 (2002)]. The turbulence structure is also drastically modified with this control. The quasi-streamwise vortices completely vanished and alternating spanwise roller-like structures formed instead.