Numerical investigation of drag reduction in turbulent channel flow by rigid fibers using a direct Monte-Carlo method

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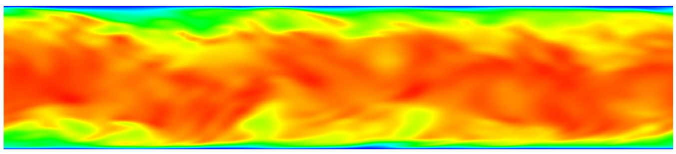
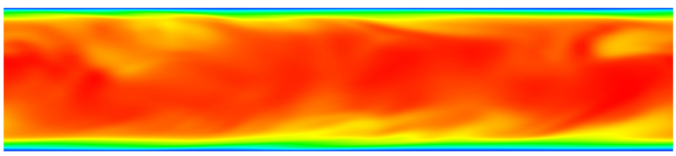
Abstract

Addition of a small amount of fibrous or flexible polymers can dramatically reduce the frictional drag in turbulent wall flows. This effect is of technical interest in liquid transportation, e.g. oil pipe systems and fire fighting devices. Detailed numerical investigation of the drag reducing effect of polymeric additives has become feasible in the last decade, and has shed some light on the physical mechanisms of drag reduction. In this work, numerical study of the fiber-induced drag reduction in turbulent channel flow at $Re_\tau = 180$ is presented. The flow field is computed using direct numerical simulation (DNS) of Navier-Stokes equations in an Eulerian frame. The fibers are considered in a Lagrangian frame using a particle tracking scheme. The fiber conformation is computed by a direct Monte-Carlo solver. The Eulerian DNS and the Lagrangian Monte-Carlo solvers are two-way coupled. The Monte-Carlo method has the advantage that it does not require any closure model. The Lagrangian treatment of the suspended fibers is chosen because the underlying equation is purely convective, which is difficult to solve in an Eulerian frame without introducing numerical diffusion. We present the numerical algorithm and discuss the results, including first- and second-order statistics and the vorticity field.



(a)



(b)

Figure 1: Streamwise velocity contours of (a) Newtonian and (b) drag-reduced flows.

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