Drag reduction with wall-attached ferrofluid films in a turbulent channel flow

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In the past decades, there has been significant interest in drag reduction techniques within the context of turbulent flows. This attention is largely driven by the need to lower energy consumption when driving fluids through conduits or moving a vessel through a fluid. A variety of drag reduction methods have been developed, including passive techniques such as oscillatory wall motion[1] and manipulation of fluid rheology[2].

Here we explore a novel technique based on a ferrofluid coating held in place by magnetic force and we investigate the effect of ferrofluid layer instability on turbulent drag reduction. We in particular focus on cases of high carrier fluid velocity or low magnetic field intensity that can lead to an instability in the ferrofluid layer.[3] We conduct experiments in a turbulent channel flow with a ferrofluid-coated wall subjected to a moderate magnetic field applied through an external magnet. To measure drag at the interface between the carrier fluid and ferrofluid layer, simultaneous 2D particle tracking velocimetry (2D-PTV) and interface detection are used (figure 1(a)). The results show that significant drag reduction can be achieved despite ferrofluid layer instability (see figure 1(b)). However, the reduction is limited as the carrier fluid's drag force intensifies, eventually leading to layer detachment.

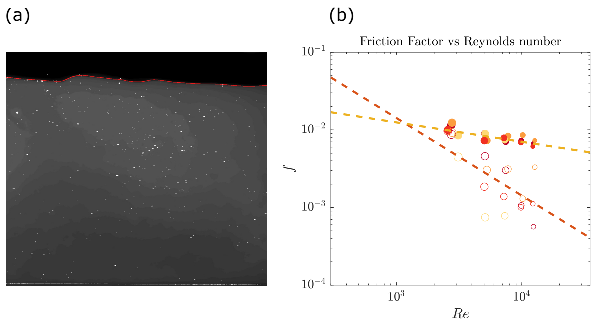

Figure 1: (a) Snapshot of a raw image for simultaneous 2D-PTV and interface detection. (b) Friction factor $f = 2\tau_w/\rho U$ against the Reynolds number $Re = hU/\nu$, for rigid- (filled symbols) and coated-wall (open symbols) at different intensities of the magnetic field (magnetic filed intensity increases with the color intensity), where, τ_w is the shear stress at the rigid/coated wall, ρ carrier fluid density, U average velocity, h the channel height and ν the carrier fluid cinematic viscosity.

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[1] Quadrio et al., *J. Fluid Mech.* **627**, (2009).

[2] Sreenivasan and White, *J. Fluid Mech.* **409**, (2000).

[3] Kögel et al., *J. Fluid Mech.* **505**, (2020).