Polymer-induced turbulence in 2D micro-serpentine channel

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Due to the concurrent effects of elastic forces, dilute suspensions of polymers can exhibit erratic fluctuations of their flow even in the case where the viscous forces dominate the inertial ones (i.e., vanishing Re). Such a flow state, first detected in a series of experiments by Groisman and Steinberg around 2000, has been called, by analogy, Elastic Turbulence (ET)[1]. ET can be generated in small-scale laboratory settings and has appeared from the very beginning as relevant to enhancing the mixing efficiency and heat transfer in microfluidic devices. To this end, we conduct extensive direct numerical simulations of the two-dimensional curvilinear channel flow of an Oldroyd-B viscoelastic fluid in ET conditions, i.e., inflow conditions of vanishing Re and high Weissenberg numbers (Wi). Static point-like numerical probes are placed at several different locations in the flow. The data from such a probe array allow us to precisely assess the degree of inhomogeneity of the flow, see Fig. 1. The single point statistics, specifically the probability distribution functions of velocity components and their increments, reveal features qualitatively similar to the ones known from experimental measurements, which are reminiscent of high-Re turbulence. However, the flow isotropy is not recovered even for the smallest time lags. For both components, the spectra of velocity fluctuations display power-law ranges with exponents close to -4 independently of the probe position. This is in close agreement with experimental[2] and numerical[3] observations. Lastly, we focus on global convective heat transfer performance along curvilinear channels. The variations of heat transfer coefficients and Nusselt numbers along the serpentine channel were analyzed to reveal the global characteristics of ET. Substantial enhancement of mixing was observed with increasing Wi. This is particularly attributed to the increasing intensity of elastic instability resulting from the balance between normal stresses and streamlined curvatures.

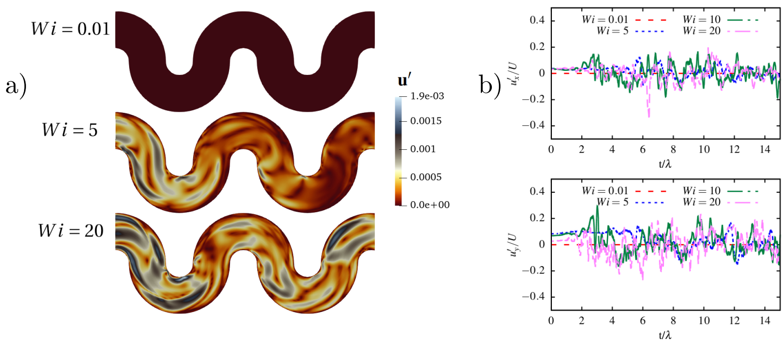

Figure 1: (a) Instantaneous velocity fluctuations magnitude and (b) time series of normalized velocity fluctuations as a function of Wi.

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[1] A. Groisman and V. Steinberg, *Nature* **405**, 53-55 (2000).
[2] A. Souliés et al., *Phys. Fluids* **29**, 8 (2017).
[3] H. Garg et al., *Phys. Rev. E* **104**, 035103 (2021).