Suspensions of finite-size elastic fibers in ideal turbulence

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We investigate the dynamics of flexible fibres dispersed in statistically stationary, homogeneous and isotropic turbulence (Fig. 1) by means of direct numerical simulation (DNS) and an immersed boundary method to mutually couple the solid and fluid dynamics. We explore the effect of the main properties of the suspension by systematically varying, in particular, the fibres' linear density, length and bending stiffness, as well as the concentration of the dispersed phase, thus spanning a wide parametric space. Results provide insight on both the modulation of the carrier flow and several features of the fibres' dynamics, such as the flapping states and deformation, as well as clustering and preferential alignment.[1] Specifically, we describe a scale-by-scale turbulence modulation mechanism that is primarily governed by the mass fraction of the suspension (with only a minor influence of the fibre's bending stiffness), resulting in an overall depletion of the turbulent kinetic energy along with a relative increase of the small-scale energy content. Hence, we show that the fiber's deformation (focusing, in particular, on their maximum curvature) varies with the characteristic turbulence and structural properties according to different scaling laws that can be derived theoretically from the fibre's dynamical equation. Lastly, we characterize the clustering of the dispersed phase in terms of the radial distribution function over pairs of fibres, and look at the preferential alignment between the fibre's local orientation and the surrounding flow's strain rate principal directions, highlighting for both phenomena the peculiar role of inertia and flexibility and outlining potential future developments.

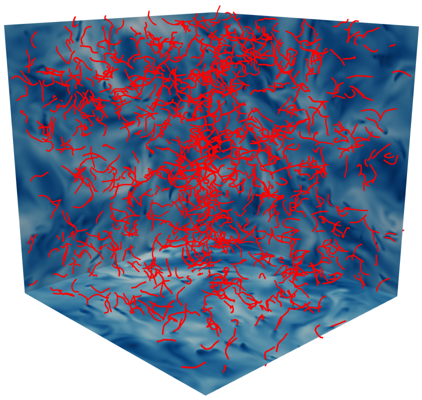

Figure 1: Snapshot from one of the performed DNSs where finite-size elastic fibres (in red) are dispersed in homogeneous isotropic turbulence. The domain backplanes of the tri-periodic box are coloured by the fluid velocity magnitude (increasing with brightness).

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[1] Olivieri, Mazzino and Rosti, *J. Fluid Mech.* **946**, A34 (2022).