Dynamics of flexible fibres immersed in viscoelastic fluids

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We investigate the dynamical behaviour of flexible fibres suspended freely in a viscoelastic turbulent flow. Direct numerical simulations were performed in a flow sustained by an Arnold-Beltrami-Childress forcing, where the backreaction of the fibre to the flow is implemented by an immersed boundary method. We conduct a parametric study across different Deborah numbers (De) by varying the fibre's bending stiffness γ (from flexible to rigid fibres) and the linear density difference between the fibre and the flow $\delta\rho$ (from iso-dense to denser than the fluid fibres). For fibres suspended in Newtonian flows, two different flapping regimes were identified by Olivieri et al[1]: one dominated by time-scales from the flow, and another by time-scales associated with the fibre's natural frequency itself. In the present work, we explore how the flow and fibre dynamics may be modified due to viscoelasticity. Results reveal that for the iso-dense configuration, the fibres primarily oscillate as a combination of the mean flow frequency and frequencies arising out of the flow turbulence, as shown in Fig. 1. For the denser than the fluid fibres, a similar trend holds except for highly rigid fibres which oscillates with their natural frequency (Fig. 1). It is also observed that higher frequencies which are close to the eddy frequency at the fibre's length scales are excited for the iso-dense configurations. In addition, we also explore the fibre's bending curvature, its preferential alignment with the flow and other flow macroscopic behaviours such as its energy spectrum across different De to identify the role of viscoelasticity in modifying the classical turbulence spectrum.

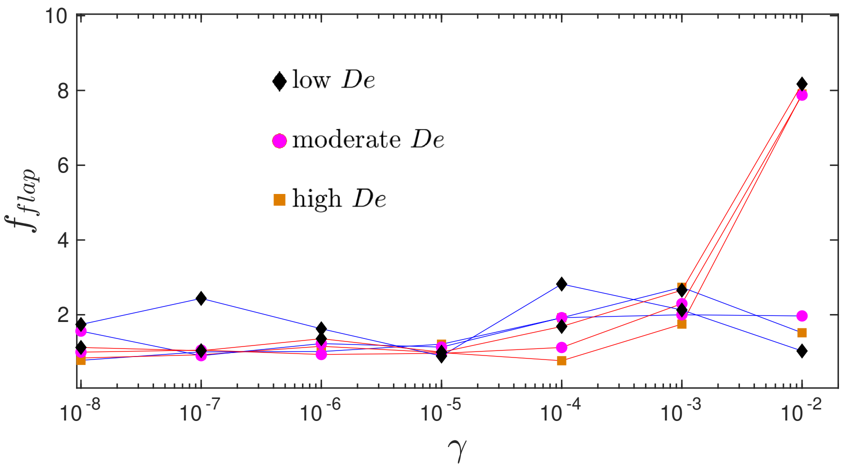

Figure 1: The dominant flapping frequency f_{flap} of the fibre, as a function of the bending stiffness γ for low, intermediate and high Deborah numbers De. The blue and red colors represent the iso-dense and denser than the fluid configurations respectively.

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[1]Olivieri et al., *J. Fluid Mech.* **946**, (2022).