Receptivity to finite-size perturbations in pipe flows for yield-stress fluid

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Résumé

Transition to turbulence in channel and pipe flow is one of the most investigated fields in fluid mechanics. It relies on non-trivial phenomena that are not yet fully understood since the experiments of O. Reynolds in 1883. In addition to the fundamental knowledge, having a comprehensive view of the transition to turbulence can help us to control the complex systems encountered in industrial processes. In industrial wastewater treatment plants, which manipulate yield-stress fluids, the accurate prediction of laminar-turbulent transition is critically important. Slatter (2004) [1] emphasizes the necessity to provide a more precise understanding of turbulence to design an efficient fluid transport in the pipe.

Laminar-turbulent transition in pipe flow is dominated by nonlinear interactions between finite-amplitude perturbations [2,3], as the Hagen–Poiseuille flow is linearly stable. Among the most interesting features of transition to turbulence in pipe flows there is the phenomenon of intermittent turbulence, where small turbulent regions (*puffs*) grow up to larger turbulent patches (*slugs*) and then they could decay owing to a relaminarization process.

The present work investigates the non-linear physics in the momentum equation that are essential to explain the intermittency, as well as the non-linear interaction between turbulent and laminar regions leading to transition. An extension of our recent model developed in [4] is here proposed for a sludge-behavior fluid, by introducing an Herschel-Bulkley yield-stress constitutive law. This is taken into account within the axial and radial derivatives of the viscous term in the axial momentum equation. Several parameters ($\mathcal{R}$,Hb,r) are considered in order to identify the impact of the receptivity to the finite-size perturbations on laminar-turbulent transition. A difference in laminar-turbulent transition along the radius position r is highlighted (see Fig.1). We aim here to provide a first insight on the receptivity to finite-size perturbations for non-Newtonian fluids described by an Herschel-Bulkley rheological model.

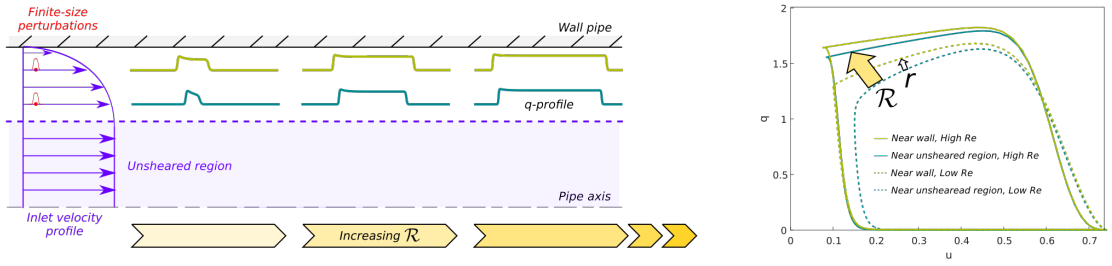

Figure 1. Receptivity to finite-size pertubations for a sludge representative set of paramaters in a pipe

Références

1. P.T. Slatter, Water SA, 30, 5 (2005).
2. B. Hof, C. W. H. van Doorne, J. Westerweel, F. T. M. Nieuwstadt et al., Science, 302, 1594-1598 (2004).
3. F. Waleffe, Phys. Fluids, 9, 883-900 (1997).
4. F. Romanò, A. Charles, F. Dottori, S. A. Bahrani., Phys. Fluids, 33, 091702 (2021).
5. D. Barkley, Phys. Rev. E, 84, 016309 (2011).