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Streak instability in viscoelastic Couette flow

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The secondary instability of streaks and transition to turbulence in viscoelastic Couette flow are studied using direct numerical simulations (DNS). Viscoelasticity is modelled using the FENE-P constitutive equations, and both the polymer concentration and Weissenberg number Wi are varied in order to assess their effect on transition at moderate Reynolds number, $Re = 400$. The base streaks are obtained from nonlinear simulations of the Couette flow response to a streamwise vortex, and can be classified as quasi-Newtonian streaks according to the terminology introduced by Page & Zaki [1]. We choose the initial amplitude of the vortex in order to have a constant maximum amplitude of the streaks during their temporal evolution. Nonetheless the mean energy of the streaks decreases at higher Weissenberg number. The growth of streaks in both Newtonian and non-Newtonian flows is primarily due to the longitudinal vorticity, but is but is also affected by the polymer torque [2]. The torque exerted by the polymers along the longitudinal direction opposes the vorticity and lowers the streak growth at large Weissenberg number.

At every streak amplitude of interest, harmonic forcing is introduced along the transverse direction to trigger the secondary instability and breakdown to turbulence. We demonstrate that (i) the critical amplitude of the forcing A_d decreases at low Weissenberg number, while (ii) A_d increases at large Weissenberg number. The degree of stabilisation due to elastic effect depends on the initial value of the strength of the streaks, A_s. For weak streaks the critical amplitude for secondary instability is more sensitive to Wi than for strong streaks. This is explained by the existence of two different mechanisms that can trigger transition to turbulence [3]. In particular, the normal vorticity is found to play a fundamental role in the breakdown of weak streaks. At large Weissenberg number the polymer torque along the normal direction is opposing the vorticity and hinders the transition. The secondary instability of strong streaks is much less immune to this stabilising effect of the polymer.

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