Stability problems in parallel shear flows of visco-plastic fluids

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We present results from two interesting visco-plastic fluid flows.

Firstly, we consider the stability of a multi-layer plane Poiseuille flow of two Bingham fluids. It is shown that this two-fluid flow can be more stable than the equivalent flow of either fluid alone. This result is in direct contrast to the stability of analogous flows of purely viscous generalised Newtonian fluids, for which short wavelength interfacial instabilities can be found at relatively low Reynolds numbers. The results imply the existence of parameter regimes where visco-plastic lubrication is possible, permitting transport of an inelastic generalised Newtonian fluid in the centre of a channel, lubricated at the walls by a visco-plastic fluid, traveling in a stable laminar flow at higher flow rates than would be possible for the single fluid alone.

Secondly, we present new results on the nonlinear stability of Bingham fluid Poiseuille flows in pipes and plane channels. These results show that the critical Reynolds number for transition, Re_c, increases with Bingham number, B, at least as fast as $Re_c \sim B^{1/2}$ as $B \to \infty$. Estimates for the rate of increase are also provided. We compare these bounds and existing linear stability bounds with predictions from a series of phenomenological criteria for transition, as $B \to \infty$, concluding that only Hanks' (1963) criteria can possibly be compatible with the theoretical criteria as $B \to \infty$. In the more practical range of application, $0 \leq B \leq 50$, we show that there exists a large disparity between the different phenomenological criteria that have been proposed.