Elastic instabilities in entry flows: A consequence of upstream stretch or downstream relaxation?

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In this paper we investigate the flow of dilute to semi-dilute solutions of polyethylene oxide through planar abrupt 16:1 microfabricated contraction geometries. This study extends previous work on micron-scale entry flows, in which strong viscoelastic effects could be generated in weakly elastic fluids, merely by reducing the lengthscale of the device. As with the previous study, the flow behaviour upstream of the contraction plane is characterized according to a number of flow regimes including Newtonian-like flow, steady viscoelastic flow, inertio-elastic instabilities, and vortex growth, which occur over a range of Reynolds numbers, $0.2 < Re < 40$ and Weissenberg numbers, $0 < Wi < 140$. In the present work, we specifically explore the effect of the *contraction length and downstream expansion geometry* on the upstream kinematics, which are quantified using streak imaging and micron-particle image velocimetry. Velocity field data is accompanied by pressure drop measurements over the contraction, which provide further insight into the importance of contraction length and the resulting viscoelastic response of the fluid. It was found that the overall effect of changes to the downstream geometric variables is to stabilize the flow upstream of the contraction (for the same Reynolds and Weissenberg numbers!) thereby suppressing so-called "inertio-elastic" effects upstream of the contraction. Such "inertia-like" time-dependent flow structures were previously attributed to the interplay of fluid elasticity and inertia, however the present work suggests that these elastic phenomena are more a function of the flow configuration both upstream and downstream of the contraction, and are not purely inertia related. These findings are highly relevant to the performance of microfluidic devices, agricultural spray nozzles and inkjet printing devices, all of which involve the transport of weakly elastic fluids through micron-scale confined flow geometries.