Optimisation of a microfluidic converging channel for extensional measurements

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Abstract: Strong extensional flows are important for many scientific and industrial applications, especially for non-Newtonian fluids where measurements of extensional properties, such as extensional viscosity, are important. Converging geometries are known for their ability to stretch the fluid in a strong extensional flow along the centreline [1]. At the macroscale, converging channels used as extensional rheometers are usually axisymmetric and operate only with highly viscous fluids to reduce inertial effects. Microfluidic flows are characterised by high deformation rates under small Reynolds numbers (*Re*),offering a promising platform for investigating fluids described by complex rheological behaviour.

The shape of the converging geometry must be carefully designed for achieving the desired velocity profile, and producing a region of homogeneous extensional flow with constant strain rate. The total strain experienced by a fluid element is quantified using the total Hencky strain $\varepsilon_H = ln(w_u/w_c)$, where w_u is the upstream width and w_c is the minimum width at the contraction. An in-house CFD code based on a fully-implicit finite volume method [2] combined with a mesh deformation code based on NURBS, are coupled with NOMAD optimiser [3] for optimising the shape of a converging geometry, that approaches the target velocity and strain-rate profiles for various ε_H. Newtonian fluids were examined under creeping flow conditions ($Re \to 0$), which is a reasonable approximation in microfluidics, considering a 2D fluid flow and then extended to 3D. Following that, geometry optimisation was performed for a viscoelastic fluid using the Oldroyd-B model, and its response was assessed for increasing Deborah numbers.

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