MICROFLUIDIC CONVERGING-DIVERGING CHANNELS OPTIMISED FOR PERFORMING EXTENSIONAL MEASUREMENTS

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Abstract Converging channel optimisation, Extensional flow, Microfluidics, Extensional rheometer.

Microfluidics refers to the science and technology that deals with devices which manipulate and examine fluid flows in small scaled systems (1µm - 1000µm). The possibility of such microfabricated channels to replicate the natural environment at the dimensional scale of many biological and industrial processes, together with the small amount of volume sample they require, increased rapidly their popularity in many fields (i.e. biotechnology, engineering etc.). Additionally, microfluidics offers the ability to produce fluid flows that are characterised by high deformation rates under small Reynolds numbers (Re), offering a promising platform for investigating fluids described by complex rheological behaviour. That way, important viscoelastic effects that are usually masked by inertia at the macroscale are realised at the microscale and can be thoroughly investigated.

Scientific and industrial applications that handle non-Newtonian fluids are numerous and often generate strong extensional flows. Therefore, measurements of extensional properties, such as extensional viscosity, are of high importance. Converging geometries force the fluid to flow from a wide cross-section region of width w_u, through to a contraction region with minimum width w_c. Contraction flows are well known for their ability to stretch the fluid in a strong extensional flow along the centreline [1], where the total strain experienced by a fluid element is quantified using the total Hencky strain, $\epsilon_H = ln(w_u/w_c)$.

A converging-diverging microfluidic geometry is optimised in this work for achieving the desired (target) velocity profile (figure 1a) and producing a region of homogeneous extensional flow of constant strain rate. A combination of an in-house CFD code, based on a fully-implicit finite volume method [2], and a mesh deformation code based on NURBS, is coupled with NOMAD optimiser [3] in order to optimise the shape of the geometry for various ϵ_H. Initially, 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 (figure 1b) . The onset of elastic instabilities as well as the effect of Reynolds and Deborah numbers are evaluated to study the practical limits of applicability of these designs.

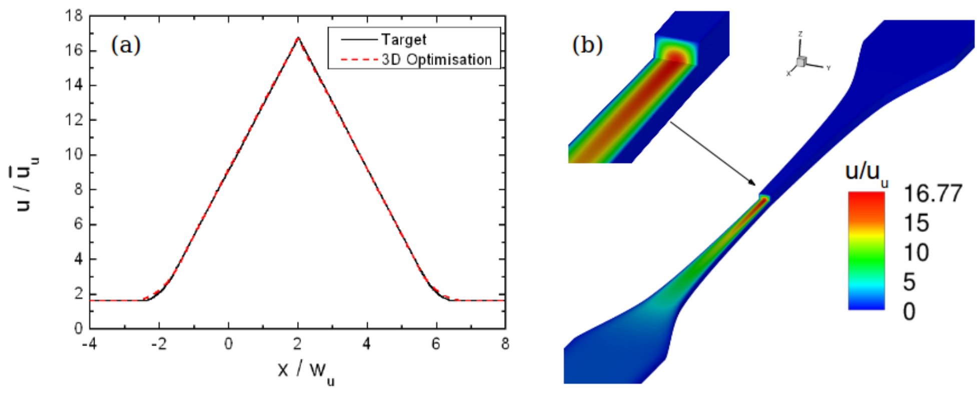

Figure 1. Velocity profile of the optimised solution versus the desired target profile, along the centreline of the channel for a Newtonian fluid (a) and dimensionless velocity contours for an optimised 3D converging geometry (b) with $\epsilon_H = 2$.

References

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