Long abstract

MICROFLUIDICS WITH COMPLEX FLUIDS

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The nonlinear rheological behavior of complex fluids, also called non-Newtonian fluids, imparts a rich set of unusual characteristics to their flows in contrast to what is observed for the so-called Newtonian fluids. The non-linear features of non-Newtonian fluids are enhanced by the small sizes typical of microfluidic channels, since some of the driving flow mechanisms of complex fluid flow are inversely proportional to the geometric length scale and these terms come to dominate the flow dynamics at the small scales.

In this lecture, some of these interesting features will be shown through both experimental and numerical research that our research group has been carrying out over the last 6 years. The lecture will start with a brief description of the main governing equations and relevant dimensionless numbers highlighting the differences relative to Newtonian fluid flows. Then, it will follow with a short overview of the experimental and numerical techniques used and will proceed with the presentation of the results, the main body of the presentation. These will show various examples of flow instabilities in flows at negligible Reynolds numbers, which are driven by the elastic properties of the fluids.

The flows investigated contain a non-negligible extensional flow contribution, but are also affected by shear effects. We start here with the classical cross slot flow of polymer solutions and the dependence of the viscoelastic flow transitions on the Reynolds (*Re*) and Weissenberg (*Wi*) numbers. The flow through a single hyperbolic contraction and sudden expansion precedes the microfluidic diodes made from series of elements containing contractions/expansions. The enhanced extensional nature of the flow in the hyperbolic-based geometries is shown to lead to higher diodicities. In another interesting application, the flow of polymer solutions through consecutive contractions/expansions is shown to possibly emulate the flow through porous media.

At the end, we present numerical results of the flow of model polymer solutions/melts through the benchmark two-dimensional 4:1 sudden contraction at negligible *Re* and increasing *Wi* complemented with recent experimental data on the planar 3D contraction/expansion. The flows are steady at low *Wi*, but then go through a rich sequence of transitions as *Wi* increases. They become time dependent, but fairly organized, then a frequency doubling mechanism sets in and this is followed by a subsequent regime of chaotic-like behavior with back-shedding of vorticity as we keep increasing the Weissenberg number. Although the various numerically-computed and experimentally-observed transitions take place at different values of *Wi* they are qualitatively similar and related to elasticity since *Re* is kept negligibly small.

Lines of future research will close the presentation.