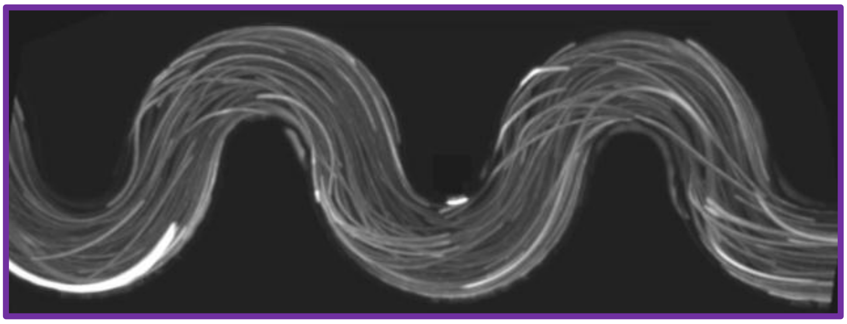
Purely elastic instabilities in serpentine channels

Anke Lindner[1], Josephine Zilz[1], Rob J. Poole[2], and Manuel A. Alves[3]
[1]*Laboratoire PMMH-ESPCI, Paris, France;*
[2]*School of Engineering, University Of Liverpool, Liverpool L69 3GH, United Kingdom;*
[3]*CEFT, Departamento de Engenharia Química, Universidade do Porto, Porto 4200-465, Portugal*

Purely elastic instabilities are known to occur in flows with curved streamlines of viscoelastic fluids at low Reynolds numbers (Re). They have recently attracted renewed interest as they have been shown to increase mixing in wavy microchannels [1]. The onset of instability has been proposed to be a function of the balance between streamline curvature and hoop normal stresses [2], but the exact form of this relation is scarcely studied, in particularly for channel flow. Here we report the results of a combined experimental and numerical investigation of variation of the instability threshold with the channel curvature.



The experimental study is performed for a dilute polymer solution in a wavy microchannel. The channel of width W comprises a series of half loops of radius R which is systematically varied. We have analyzed the critical Weissenberg number (Wi_c) at which the flow becomes unstable as a function of the geometry of the channel and the properties of the polymer solution.

The numerical simulations study the creeping flow limit (Re = 0) for a viscoelastic fluid obeying the upper-convected Maxwell model. Two-dimensional simulations matching the experimental conditions show that above a critical Weissenberg number the flow becomes unsteady. Good qualitative agreement between experiments and simulations is obtained and we show that the instability onset Wi_c is proportional to the square root of R/W with a small offset when R/W tends towards zero. These results are confirmed by a simple scaling argument following the Pakdel-Mckinley criterion [2].

[1] A. Groisman and V. Steinberg, New J. Phys. 6, 29 (2004).
[2] P. Pakdel and G. H. McKinley. Physical Review Letters, 77(12):2459-2462, 1996.