Purely-elastic instabilities in serpentine channels

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ABSTRACT

Purely elastic instabilities are known to occur in flows with curved streamlines in viscoelastic fluids at low Reynolds numbers. 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 curvature and normal stress effects [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.

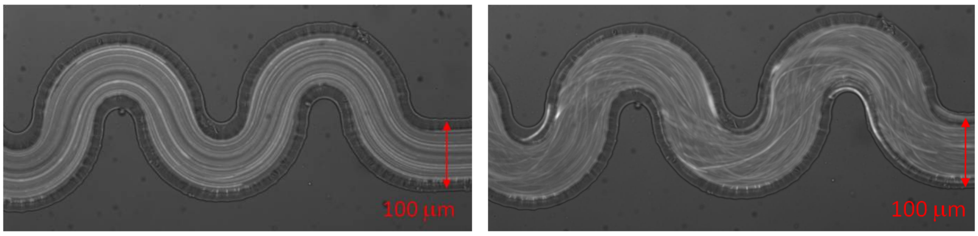

Figure 1: *Flow visualization using streak lines. Left: stable flow. Right: unstable flow*

The experimental study is performed for a dilute polymer solution in a wavy microchannel. We have analyzed the critical Weissenberg number (Wi) at which the flow becomes unstable as a function of the geometry of the channel and the properties of the polymer solution. For this purpose we utilize a microfluidic channel of width (side-length) 25 μm to 100 μm and aspect ratios (width over height) between 0.5 and 2. The channel comprises a series of half loops of radius R which is systematically varied in the range 25 μm $<$ R $<$ 2000 μm. We use solutions of a high molecular weight polyethylene oxide (Mw=10^6 and 4x10^6) in various glycerine/water solvents. The instability onset is defined via visualizations of fluctuations within the flow. We systematically investigate the effects of channel curvature and aspect ratio and the effects of solvent viscosity, molecular weight and polymer concentration.

The numerical simulations study the creeping flow (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. The scaling for this critical Wi is in good qualitative agreement with the experiments.

REFERENCES

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[2] P. Pakdel and G. H. McKinley. *Elastic instability and curved streamlines.* Physical Review Letters, **77** 2459-2462, 1996.