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STRESS-GRADIENT INDUCED MIGRATION IN THIN FILM FLOW OVER TOPOGRAPHY

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We consider the two dimensional, steady flow of a viscoelastic polymer solution over a periodic topography under the action of a body force. We are interested in examining how the distribution of polymer in the planarization of various topographical features is affected by flow and physical properties through a parametric analysis. The Mavrantzas-Beris two-fluid Hamiltonian model is used in order to allow for polymer migration; a model which is based on non-equilibrium thermodynamics. The resulting complex system of differential equations is solved via the mixed finite element method combined with a quasi-elliptic grid generation scheme for the tessellation of the physical domain resulting by the highly deformed free surface. We use the SUPG method for the weighting of the constitutive equations along with the EVSS-G splitting method for the computation of the elastic stresses and a local mesh refinement around the convex corners of the geometry. We present numerical results for polymer concentration, stress, velocity and flux of components as a function of the non-dimensional parameters of the problem (the Deborah, the Peclet, the Reynolds and the Capillary numbers, the ratio of the solvent viscosity to the total fluid viscosity and the geometric features of the topography, such as depth, length, etc.). Polymer migration is enhanced by the variability of the channel: the steeper and deeper the cavity, the stronger the transfer of polymer to the free surface of the film (Fig. 1(a)). This increases the spatial extent of the polymer depletion layer and induces strong banding in the stresses away from the substrate wall (Fig. 1(b)), especially in low polymer concentration; phenomena that the homogenous Oldroyd-B model cannot capture. Macromolecules with longer relaxation times are predicted to migrate towards the free surface more easily, while high surface tension combined with a certain range of Reynolds numbers can give rise to large deformations of the free surface.

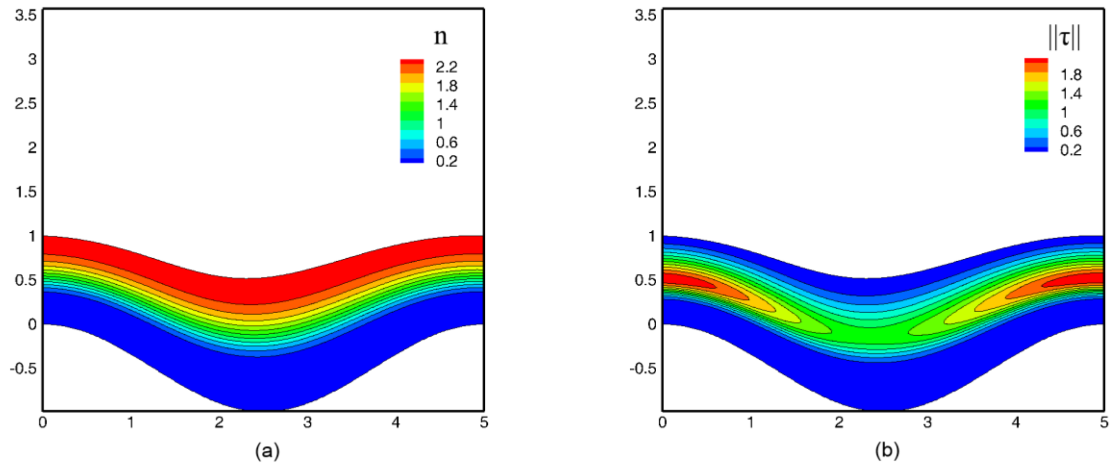

Figure 1. Flow of an inhomogeneous viscoelastic film over a periodic topography: contour plots of the number density of macromolecules (a) and the second invariant of the viscoelastic part of the stress tensor (b).

REFERENCES

[1] V.G. Mavrantzas and A.N. Beris, "Modelling the rheology and the flow-induced concentration changes in polymer solutions", *Phys.Rev.Lett.* Vol. **69**, pp. 273-276, 1992; Errata **70**, pp. 2659, 1993.

[2] M. Pavlidis, Y. Dimakopoulos and J. Tsamopoulos, "Steady viscoelastic film flow over 2D topography: I. The effect of viscoelastic properties under creeping flow", *J. Non-Newtonian Fluid Mech.* Vol. **165**(11-12), pp. 576-591, 2010.

[3] S. Tsouka, Y. Dimakopoulos and J. Tsamopoulos, "Stress Gradient Induced Migration of Polymers in Corrugated Channels", submitted to *J. Rheol.*, 2013.