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### Elastic turbulence in DNA solutions measured with optical coherence tomography velocimetry

A V Malm and T A Waigh

University of Manchester, UK

Flexible polyelectrolyte solutions display complex non-linear flow phenomena which include wall slip and elastic turbulence. We investigated the flow instabilities of solutions of high molecular weight DNA using a recently developed optical coherence tomography velocimetry technique [1]. The apparatus provides high spatial (3.4 pL) and temporal resolution (sub μs) information on the flow behavior of complex fluids in a stress controlled rheometer [1,2,3]. Velocity profiles of the DNA solutions were measured as a function of the distance across the gap of a plate-plate rheometer, and their evolution as a function of shear rate was measured. At low DNA concentrations and low shear rates the probability of the velocity fluctuations are well described by Gaussian functions and the velocity gradient is uniform across the gap of the parallel plate rheometer geometry, as expected for Newtonian flows. As the DNA concentration and shear rate were increased there was a *stable wall slip regime* followed by an *evolving wall slip regime*, which is finally followed by the onset of *elastic turbulence*. A dynamic phase diagram for non-linear flow was created to describe the different behaviors. The velocity fluctuations are intermittent in the elastic turbulence regime i.e. fat tails are superposed on the Gaussian fluctuations that demonstrate sporadic bursting events of increased DNA flow velocity. The power spectral density of the velocity fluctuations follow a characteristic scaling on frequency of $P(\omega) \sim \omega^{-\alpha}$, where $\alpha$ occurs over the range 0.5 to 3.5 dependent on polymer concentration. The Kolmogorov scaling prediction is $\alpha=5/3$ for turbulent simple fluids, whereas $\alpha>3$ is expected from theories of elastic turbulence [4,5].

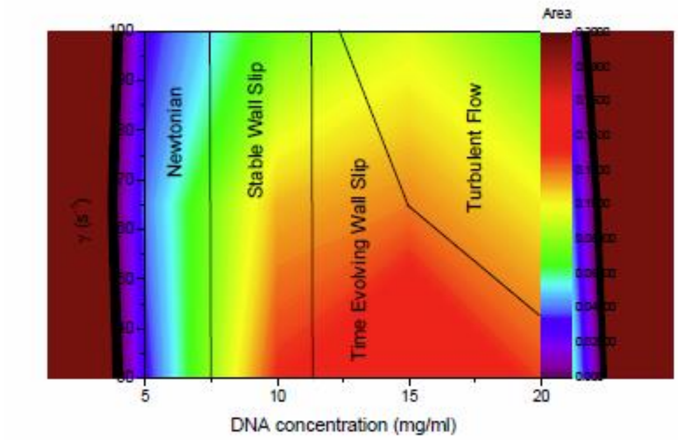


Figure 1: Phase diagram of the different types of flow for DNA solutions as a function of the applied shear rate and the concentration of the DNA. The color map shows values of the integrated area of each velocity profile as a function of depth subtracted from the constant gradient expected for Newtonian flows. The boundaries between the different flow regimes are also shown.

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[2] S.Jaradat, M.Harvey, T.A.Waigh, 'Shear-banding in polyacrylamide solutions revealed via optical coherence tomography velocimetry', *Soft Matter*, 2012, 8, 11677

[3] A.V.Malm, A.W.Harrison, T.A.Waigh, 'Optical coherence tomography velocimetry colloidal suspensions', *Soft Matter*, 2014, 10, 8210

[4] A.Groisman, V.Steinberg, 'Elastic turbulence in a polymer solution flow', *Nature*, 2000, 405, 53- 55.

[5] A.Fouxon, V.Lebedev, 'Spectra of turbulence in dilute polymer solutions', *Physics of Fluids*, 2003, 15, 7, 2060-2072