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Shear Banding and Flow Instabilities in Entangled Polymer Solutions

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Entangled polymer solutions relax their stress by the reptation mechanism, in which polymers slither or "reptate" along their length. The original theory for this, due to Doi and Edwards (DE), has successfully captured many features of polymer dynamics. For applied shear rates much faster than the reptation time, the original DE theory predicts an instability due to the alignment of the "tubes" that constrain the polymer. This instability could lead to shear banding, in which the fluid can break into regions flow at different shear rates. For decades this had not been observed in entangled polymers, and DE theory has been modified to incorporate crucial missing physics, which could eliminate the original instability. Recent experiments by a number of groups on polymer solutions show macroscopic flow inhomogeneities consistent with the original DE instability and shear banding, but have been interpreted in other ways. I will discuss the predictions of the DE and related theories for flow inhomogeneities under strong flow conditions, and show that many, *but not all*, of the recent experiments can be explained with no more new physics than is contained within DE theory. Note that most verifications and fittings of data to constitutive models (such as the DE model) assume homogeneous flow conditions: an important conclusion of this work is that one must study fully inhomogeneous flow to accurately validate these models.