124d Numerical Analysis of the Dynamics of Stretching Viscoelastic Liquid Filaments Using the Micro-Macro Brownian Configurations Fields (Bcf) Method

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A variety of engineering applications involve free surface flow of polymer solutions. Some of these applications involve predominantly extensional deformations (e.g. drop shooting in ink-jet printing etc.). A good understanding of the extensional rheology of the polymer solutions used in such applications is thus necessary for better designing of these processes. Filament stretching rheometers (Matta and Tytus 1990, Sridhar et al, 1991) which impose elongational flows in liquid columns held between two plates by continuous stretching, have been shown to be the most accurate means of determining the extensional viscosities of polymer solutions. Computational modeling of filament stretching rheometers is required to analyze their performance and also to help improve their design. Such a study of stretching liquid filaments is also important in understanding the closely related mechanism of drop formations from small nozzles (Zhang and Basaran 1996). Realistic computational modeling of deforming liquid filaments in these rheometers must incorporate viscoelasticity, capillarity, inertia and, most importantly, must track the shape of the free surfaces.

Numerical methods based on closed form continuum constitutive relations have mostly been used in such analysis (Sizaire and Legat 1997, Yao and McKinley 1998, 2000). These methods have a drawback in the sense that more realistic polymer models which have no closed form constitutive relations, such as FENE dumbbells, can not be treated with them. More realistic microscopic models can be used through Brownian dynamics simulations but such computations use pure extensional flow fields and exclude the non-homogeneous nature of the actual flow field due to the no-slip condition at the end plates. As a consequence these techniques fail to accurately match experimental observations (McKinley and Sridhar 2002, Prabhakar et al, 2004).

We present here a micro-macro approach to model filament stretching rheometers based on combining the Brownian configuration fields (BCF) method (van den Brule et al, 1997) with an Arbitrary Lagrangian-Eulerian (ALE) Galerkin finite element method. A distinct advantage of the BCF method is its ability to treat models with no exact closed-form constitutive equations and with non-linear effects such as hydrodynamic and excluded volume interactions incorporated. Also, the finite element setting enables the BCF method to use the discretized non-homogeneous flow field in calculations. These benefits of the BCF method could help in making accurate predictions of dilute polymer solution rheology in filament stretching rheometers, for which experimental data is available for comparison.