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STRONG FLOWS OF VISCOELASTIC WORMLIKE MICELLE SOLUTIONS

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ABSTRACT

The unique rheological properties of viscoelastic wormlike micelle solutions have led to their broad use as rheological modifiers in consumer products such as paints, detergents, pharmaceuticals, lubricants and emulsifiers. In addition, micelle solutions have also become increasingly important in a wide range of industrial and commercial applications including agrochemical spraying, inkjet printing, turbulent drag reduction and enhanced oil recovery. Until recently, our knowledge of the rheology and flow behavior of these fluids was limited to linear viscoelasticity measurements where wormlike micelle solutions have been shown to behave as ideal Maxwell fluids, and steady shear rheology measurements where wormlike micelles often demonstrate shear banding. In this review, we survey recent experimental and theoretical developments for nonlinear rheology of viscoelastic wormlike micelle solutions and the response of these complex fluids to strong flows. Specific emphasis will be placed on extensional rheology measurements and complex flows having strong extensional components. In many of these flows, viscoelastic wormlike micelle solutions behave in a manner very similar to polymer solutions. Wormlike micelle solutions demonstrate strain hardening of their extensional viscosity which can result in an increased resistance to complex flows such as the flow past a sphere or the flow through porous media. Additionally, the large extensional viscosity of these fluids has led to significant drag reduction in turbulent flows. However, wormlike micelles are self-assembled and as such are quite different than polymer solutions. Under large elastic stresses, wormlike micelles can break apart. This failure and the resulting morphological changes have been linked to a number of newly discovered elastic instabilities not present in polymer solutions. As this review will show, strong flows of wormlike micelle solutions hold a wealth of interesting flow phenomena much of which is yet to be explored.

KEYWORDS: Surfactant solutions; Viscoelastic wormlike micelle solutions; Extensional rheology; Shear rheology; Elastic instabilities.

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RHEOLOGICAL ISSUES IN THE PAPER INDUSTRY

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ABSTRACT

The paper industry has a number of processes where the rheology is complex and critical to control for trouble free operation. The rheological properties of pulp suspensions and paper coatings are reviewed here. The flow, rheology and other various phenomena are discussed for pulp suspensions. The particle level models that have been developed for pulp suspensions are compared to experimental results. Paper coating suspension rheology and the coating flow fields are described. Particle level models are discussed and compared to various rheological properties and process issues. Some open questions are identified.

KEYWORDS: Suspension rheology; pulp rheology; coating rheology; Stokesian Dynamics; viscoelasticity; yield stress

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FLOW AND TEXTURE MODELING OF LIQUID CRYSTALLINE MATERIALS

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ABSTRACT

A review of flow and texture modeling of liquid crystalline materials with emphasis on carbonaceous mesophases is presented. Two models of nematodynamics are presented and discussed in terms of their ability to resolve time and length scales likely to arise in typical rheological and processing flows. Defect physics and rheophysics are integrated with nematodynamics and specific mechanisms of defect nucleation and annihilation are used to derive texture scale power laws. The integrated nematodynamics models specialized to carbonaceous mesophases are used to analyze: (i) linear and nonlinear viscoelasticity, (ii) rheological flows, and (iii) carbon fiber and flow-induced textures. The linear and nonlinear viscoelasticity reveals the essential nature of these materials : coupling between flow-induced orientation and orientation-induced flow, elastic storage through orientation gradients, and anisotropy. The rheological flow simulations, shown to be in excellent agreement with experimental data, reveal several liquid crystal specific rheological characteristics including shear thinning due to anisotropic viscosities and flow-induced orientation, and negative first normal stress difference due to orientation nonlinearities in the shear stress. Nematodynamic predictions are shown to follows a Carreau-Yasuda liquid crystal equation. Nematodynamics predictions rationalize shear-induced texture refinement in terms of defect nucleation and coarsening mechanisms and are used to derive texture scaling relations in terms of macroscopic, molecular, and flow time scales. This knowledge is then condensed into a generic texture-flow diagram that specifies the required temperature and Deborah number required to produce well oriented monodomain materials. The fine details of mesophase structuring by flow through screens are shown to be captured by nematostatic simulations. Finally the mechanisms behind the carbon fiber textures produced by melt spinning of carbonaceous mesophases are elucidated. The proven range and predictive accuracy of nematodynamics to simulate flows of textured mesophases and the ever-growing industrial interest in lower cost high performance super-fibers and functional materials will fuel the evolution of liquid crystal rheology and processing science for years to come.

KEYWORDS: Rheology of carbonaceous mesophases; Discotic liquid crystals; Defect rheo-physics; Flow structuring; Carbon fiber structures