Constitutive modeling of macromolecular fluids

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1 Introduction

Macromolecular or polymeric liquids consist of polymer solutions, polymer melts, particle suspension fluids, and many biological fluids. Polymer solutions are made of polymers dissolved in solutions or solvent; polymer melts are molten polymers; particle suspension fluids consist of solid particles suspended in a matrix fluid which may be a viscous or viscoelastic fluid, blood flows consist of deformable suspensions (red and white blood cells), and mucus is characteristically viscoelastic. Given the large molecular weight and size in polymers, polymeric liquids are capable of forming a variety of meso-phases, in which partial positional as well as orientational order can be present. These meso-phases are termed liquid crystalline phases. The polymeric liquids in the meso-phases are called liquid crystalline polymers. When the meso-phases are created above some critical concentration in solutions, the polymeric liquids are called lyotropic liquid crystal polymers. When the phases are attained at certain low temperature in melts, the materials are called thermotropic liquid crystal polymers. Not only miscible polymeric solutions and melts are capable of forming the liquid crystalline phase, immiscible polymer blends, emulsions, polymer-particle nanocomposites, which are liquid mixtures of polymer solutions or melts and solid nano-sized particles, are all candidates for forming liquid crystalline phases. Polymeric liquids exhibit a host of distinctive features from the isotropic liquids consisting of small molecules like water, cooking oils, etc. in flows. They may exhibit several well-known phenomena such as rod-climbing, extruded swell, and tubeless siphon [3]. When a gas bubble is trapped within a polymeric liquid, its geometry is distinct from that of a gas bubble trapped within a Newtonian fluid. These fascinating phenomena, distinctive of the polymeric liquids, have spurted a significant amount of research activities over the past few decades. Theories and models developed for polymers are now applied to biofluids and materials, making it a fast growing interdisciplinary research area. In the lecture notes, we will first give a crash course on the basics in the continuum mechanics, which is the foundation of the more sophisticated polymer models, survey the existing models for various polymeric liquids and explore a systematic approach for flexible polymers using the framework of the kinetic theory.