Characterization of the first normal stress difference in diluted polymer solutions by tracking particle migration in a microfluidic channel

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Résumé

1. Introduction

Flows of complex liquids in porous media are involved in different fields such as in environmental remediation for removing pollutants from wastewater and soil, as well as in the field of energy with energy storage devices, drilling fluids, and enhanced oil recovery. The characterization of the properties of these complex fluids is essential to understand their behaviour, optimize their performance, and ensure their stability and effectiveness in their applications.

Polymer solution belong to the family of complex fluid, usually exhibiting viscoelastic properties. This study aims at characterizing the elastic force in viscoelastic liquids by studying the migration of particles in microfluidic devices. Contrary to Newtonian liquids in which lift forces are negligible at low Reynolds number, in viscoelastic liquids, a transverse force acts on the particles. It is due to the shear rate gradient around the particle and depends strongly on the Weissenberg (Wi) number and the ratio between the particle size and the channel size. Taking advantage on the huge aspect ratio between the length and the height of a microfluidic slit, it is possible to detect very small transverse velocities, by determining the particle trajectory. Previous studies had already shown that this phenomenon was well adapted to low Weissemberg numbers (typically 10-3 10-1), but were mainly restricted to viscoelastic fluid exhibiting a rate-independent viscosity (1)–(3). We extended these studies to the common case of shear-thinning polymer solutions.

2. Experimental results

PDFs of the particle position were systematically measured in various solutions, for various pressure drops, particle and channel sizes. For shear-thinning liquids, a less efficient migration was qualitatively evidenced, and as compared to rate-independent solutions, the PDFs exhibited various specific shapes. We also found experimentally that in some cases, when the solvent viscosity is dominant, the migration occurred towards the wall contrary to the most common case where it occurs towards the center of the channel. No accurate theory was available for shear-thinning liquids. We thus derived a model based on the assumption

*Intervenant

that the viscoelastic lift force is simply proportional to the gradient of the first normal stress difference (N1) across the particle.
Assuming additionally that it is balanced by a drag force involving the local (rate-dependent) shear viscosity, one could derived the trajectory of the particles. When both