STRIKING MANIFESTATIONS OF BOUNDARY CONDITIONS IN THE RHEOLOGY OF TUMBLING NEMATICS

A. F. Martins* and A. R. Véron

Dpt. Ciência dos Materiais and CENIMAT, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
*e-mail: asfm@fct.unl.pt

Abstract

In this work we investigated three rheological functions, namely the shear viscosity (η) and the first ($\mathcal{N}_1$) and second ($\mathcal{N}_2$) normal stress differences predicted by Leslie-Ericksen theory in complex shear flows. More precisely we examine the manifestations on measurable quantities, such as η, $\mathcal{N}_1$ and $\mathcal{N}_2$, of strong anchoring in low molecular weight liquid crystals exhibiting tumbling. The combination of strong anchoring with tumbling directly results in a complex director profile that, in turn, generates backflows. Therefore, at least two inhomogeneous time dependent velocity gradients occur instead of one single constant shear rate as for simple shear flows. Moreover, stochastic-like fluctuations are added in the director equation in order to account for the damping of the oscillating stress responses. A key point of this work lies on the fact that for such inhomogeneous flows the experimental values of $\mathcal{N}_1$ and $\mathcal{N}_2$ are quantities that probe the state of the fluid in contact with the plate on which the measurement is performed; it follows immediately that these functions, contrarily to η, are extremely sensitive to the boundary conditions. To evidence this feature we examined the transient and steady responses of η, $\mathcal{N}_1$ and $\mathcal{N}_2$ for several anchoring modes for the tumbling nematic MSHMA/5CB. Our results may be summarized as follows: (i) apart very particular cases where the normal stress differences vanish, they have the same order of magnitude as the shear stress; (ii) despite the fact that the stress tensor is linearly related to the velocity gradients, the steady values of $\mathcal{N}_1$ and $\mathcal{N}_2$ are non-linear and non-monotonous functions of the nominal shear rate with, moreover, non well-defined sign; (iii) under certain conditions the functions $\mathcal{N}_1$ and $\mathcal{N}_2$ may oscillate with a period twice the one for the shear stress response. Finally it emerges from this work that experimental studies of $\mathcal{N}_1$ and $\mathcal{N}_2$ may provide a way to shed light about the problem of boundary conditions for the director.