8TH PACIFIC RIM CONFERENCE ON RHEOLOGY, May 15-19, 2023

NONLINEAR RHEOLOGY OF ENTANGLED WORMLIKE MICELLES: A SLIP-SPRING SIMULATION STUDY

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ABSTRACT

While extensive studies made linear rheological properties of wormlike micelles (WLMs) to be relatively understood, our understanding of nonlinear rheological properties of WLMs is still poor. For deeper understanding of the rheology of WLM solutions, we developed a mesoscopic model to investigate linear and nonlinear rheological properties of entangled WLM solutions.[1] This model is based on the slip-spring (SS) model originally proposed for entangled polymers.[2] To reproduce the dynamics of wormlike micelles, breakage and rejoining events are combined with the polymer-SS model. Furthermore, we address the effects of finite extensibility of springs and stress-induced micelle breakage (SIMB), which are required to reproduce nonlinear rheological properties. After confirming that the micelle-SS model can quantitatively reproduce the linear rheological properties, we used this model to predict nonlinear rheological properties under shear and uniaxial extensional flows. We found that the micelle-SS model can quantitatively predict the shear-rate-dependent viscosity of the WLM solution with a moderate number of entanglements per micelle Z ($Z \leq 7$). Furthermore, the shear rheological properties of the micelle-SS model with moderate shear rates without the remarkable spring stretch can be reproduced by the Giesekus model, which is in agreement with the experimental finding. On the other hand, the extensional properties of the micelle-SS model have not been well tested by comparing with experiments since it is difficult to obtain reliable experimental data for WLM solutions with computationally accessible Z values. Nevertheless, we confirmed that the strain rate dependence of steady extensional viscosity predicted by the micelle-SS model with SIMB shows thickening followed by thinning, which is in qualitative agreement with the experimental observation. We hope to utilize the micelle-SS model to develop a constitutive model.

REFERENCES

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