Towards a quantitative prediction of the flow of polydisperse rod-like colloids

Christian Lang[1], Pavlik Lettinga[2 †]

[1]*Forschungszentrum Jülich GmbH, Jülich Center for Neutron Science, Lichtenbergstrasse 1, 85748 Garching, Germany.*
[2]*Forschungszentrum Jülich GmbH, Institute of Complex Systems 3, Wilhelm Johnenstrasse, 52428 Jülich, Germany* [†] *Also at : KU Leuven, Laboratory for Soft Matter and Biophysics, Celestijnenlaan 200d, 3000 Leuven, Belgium*

Their vast natural abundance and usefulness for industrial applications makes dispersions of rod-like colloids an important object to study. Of particular interest are the phase behavior and the rheological behavior of suspensions of rods. Despite the broad interest, there remains a lack of understanding of the flow behavior of semi-dilute suspensions of rods, especially in the case of particle flexibility and polydispersity. We used a combination of rheology and in-situ small angle neutron scattering to relate the macroscopic stress to the microscopic 3D orientational ordering [1,2] for a library of monodisperse rod-like viruses. We gained a complete understanding of the pronounced effect of length on the zero-shear viscosity as well as the shear thinning, see Figure 1. Moreover, we showed, using modified viruses, that an increased particle flexibility lowers the zero-shear viscosity and has no marked influence on the shear thinning behavior [3]. We exploited this result to attack the problem of polydispersity. By mixing two species of very disparate lengths to a benchmark bi-disperse suspension, we find that the average particle length determines the flow behavior. Based on the established theoretical approaches [4,5], we developed a new way of reducing the full Yvon-Born-Green cascade of Smoluchowski equations which allows us to quantitatively predict the orientation and stress of rod-like suspensions of different lengths and also of bi-disperse suspensions. With this combined theoretical and experimental study, we approach also full understanding of the flow behavior of polydisperse rods from the dilute up to the nematic liquid-crystalline state.

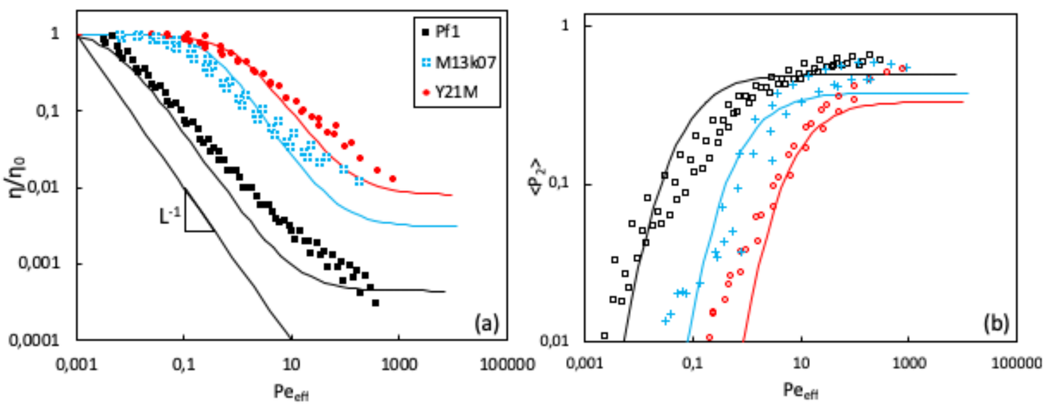

Figure 1: (a) Reduced shear viscosity and (b) orientational order parameter as a function of the effective Péclet number for Pf1 (L=1.96 μm), M13k07 (L=1.2 μm), and Y21M (L=0.91 μm) at different concentrations reduced to master-plots. Lines are novel theoretical results. The straight line in (a) shows an L^{-1} dependent viscosity, anticipated for a shear banding fluid.

References

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