Experimental report

07/03/2019

Proposal: **9-10-1522** **Council:** 4/2017

Title: Connection between Shear Banding and Hairpin Formation for Semiflexible Rods

Research area: Physics

This proposal is a new proposal

Main proposer: **Christian LANG**

Experimental team: Pavlik LETTINGA
Christian LANG

Local contacts: Lionel PORCAR

Samples: M13k07 virus
Pf1 virus

Instrument	Requested days	Allocated days	From	To
D22	3	3	12/04/2018	15/04/2018

Abstract:

The effect of particle morphology on the shear banding flow instability will be studied by means of rheo-SANS. We want to measure the orientational ordering of two very long and flexible rodlike bacteriophages at different positions in the gap, using the available shear cell of D22. From earlier experiments, we know that the systems show both, hairpin formation as well as shear banding at similar shear rates. This hints to an interdependence of these phenomena which has not been reported before.

Experimental Report (proposal nr. 9-10-1522)

The goal of the experiment was to detect shear-banding instabilities in rod-like particle suspensions by measuring the orientational ordering of two different rod-like bacteriophages under steady shear flow conditions. The chosen systems were M13k07 (l_c=1200 nm, d=6.6 nm, l_p=2200 nm) and Pf1 (l_c=1960 nm, d= 6.6 nm, l_p=2200 nm), both suspended in a 110 mM Tris buffer solution on the basis of deuterium dioxide. Since previously acquired experimental results from rheometry indicated that the longer Pf1 virus was more likely to show a gradient shear banding instability, we chose to carefully measure a large range of shear rates for Pf1 and also perform time-dependent gap scans, and did not measure the M13k07 suspensions. We prepared suspensions of Pf1 very close to the isotropic-nematic phase transition. In this concentration regime, a shear banding instability is most likely, as indicated by our preliminary rheological tests.

The rheo-SANS experiments were conducted using the 1-3 shear cell available at D22, equipped with the new gear-box transducer to access also very low shear rates. We performed a series of SANS experiments within the steady shear rate regime {0.0025,2} s^{-1}, directing the beam through the axial direction of the Couette cell, probing the flow-gradient plane, using a wavelength of 0.6±0.1 nm with a detector distance of 6.5 m. We used a 3 x 0.15 mm aperture size and probed the orientation of particles at eight positions along the gap of the cell.

After background subtraction, we calculated the averaged azimuthal intensity profile of the samples under different shear conditions at different gap positions in a q-range between $3.2x10^{-2}$ and $4.6x10^{-2}$ $Å^{-1}$, which we fitted with the function $I(\theta)=I_0 e^{C<P_2>(\theta-\theta_{max})-1}$, from which the orientational order parameter of the systems, $<P_2>$, was calculated for the given conditions. Figure **1** shows the order parameter for a highly concentrated suspension of Pf1 at different shear rates for different positions along the gap of the Couette cell, y/y_0, normalized by the location of the inner moving wall, y_0. For some specific shear rates, 0.01, 0.015, and 0.04 s^{-1}, we found a steep slope of the order parameter towards the still-standing wall, crossing-over to a less steep slope at a scaled position of 0.5, hinting at a shear banding transition for these settings.

In a subsequent laser-Doppler experiment for the very same samples, however, we could not detect any stable shear-banding instability, see Lang, C. et al. (2019) *J. Phys. D.* **52**, 074003. This result is interesting in its own right, since it indicates that the length of our particles is not high enough in order to induce a stable gradient shear banding transition.

From a time-resolved gap scan of the same material, we could find, and subsequently validate by laser-Doppler measurements, a gradient shear banding instability for approximately 5 min of applied shear, which vanished after 10 min, see Figure **2**. This indicates that, indeed, the gradient shear banding instabilities we found are not stable over time. We can attribute this to the in-effective network formation of our particles in the semi-dilute concentration regime.

Our results show that even very close to the isotropic-nematic transition, aspect ratio 300 particles with hard-core interactions do not form stable shear-bands. We suppose, however, that a further increase in contour length, and maybe also a higher flexibility of the particles, would lead to a stabilization of the shear bands.

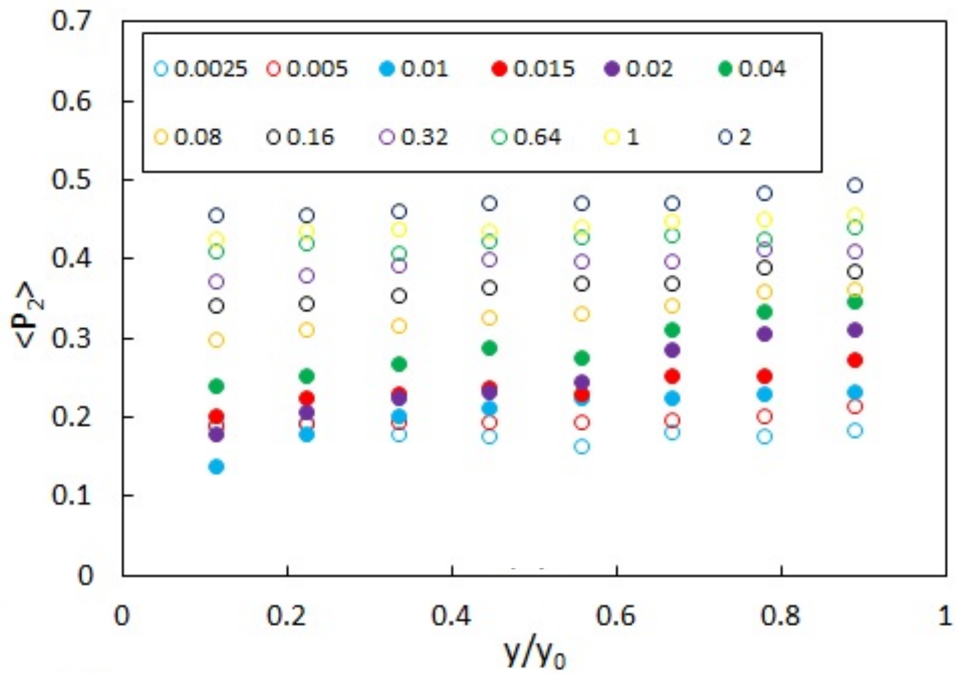

Figure 1: Orientational order parameter as a function of the scaled gap position for Pf1 at a concentration of 11.6 mg/ml for different shear rates.

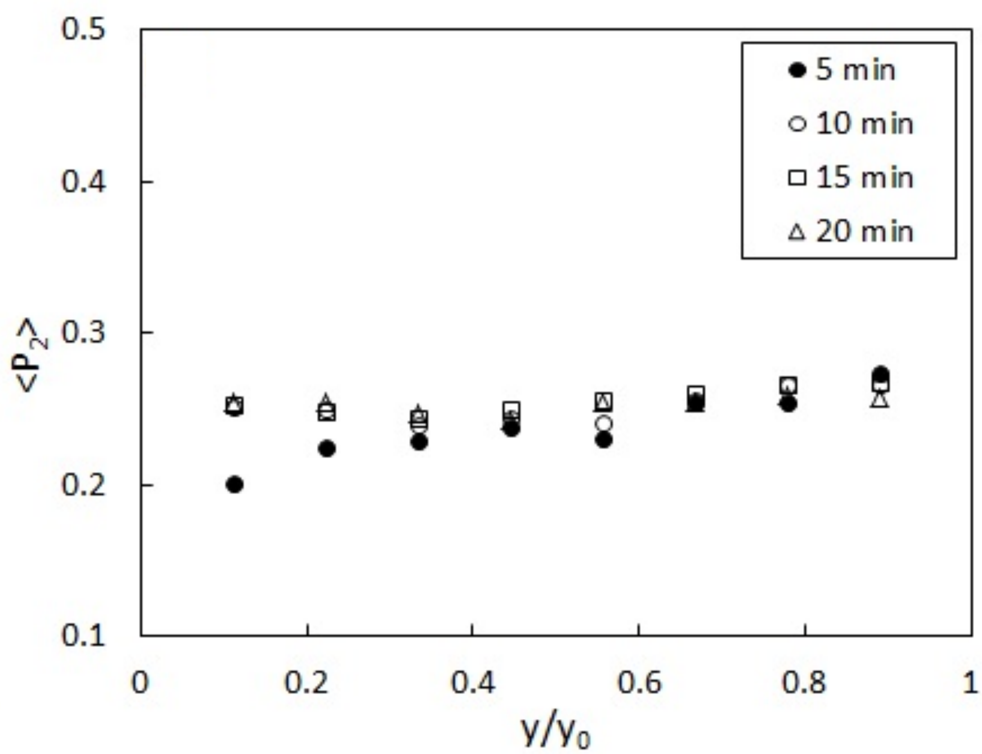

Figure 2: Orientational order parameter as a function of scaled gap position for Pf1 at a concentration of 11.6 mg/ml and a shear rate of 0.01 s^{-1} for different time-spans of applied shear.