CPP 35: Focus: Rheology I (joint focus with DRG)

Rheology is the science of flow and deformation properties of materials. It covers a vast class of materials from biological cells to synthetic polymers and from food to paint. Only the cooperation of physicists, chemists, engineers and mathematicians allows to handle such a complexity. It is the aim of the focus session to bring scientists from different fields together and allow the exchange of modern rheological methods that have been developed in different areas but can be used on a variety of systems. The first session will have a focus on biological materials and colloids and the second session on polymers. (Organizer: Christian Wagner)

Time: Thursday 15:00–18:45 Location: C 243

Invited Talk CPP 35.1 Thu 15:00 C 243
Motion of microswimmers governed by light in a fluid flow. — •Philippe Peyla, Salima Rafaï, and Xabel Garcia — Grenoble University and CNRS, LIPHY, BP 87 38 402 Saint Martin d'Heres, France

In nature, organisms that can propel themselves in a fluid medium are ubiquitous. While larger organisms, such as fish, use inertia in their motion, microorganisms like spermatozoa, microalgae or bacteria, move at low Reynolds number, where viscous forces dominate over the effects of inertia. A recent and currently unresolved issue involves understanding the hydrodynamics associated with the individual or collective motion of microswimmers through their fluid-mediated interactions. The motion of these micro-organisms is affected by the presence of gradients (chemiotaxis in the presence of chemicals, gyrotaxis in a gravity field, phototaxis under illumination). In this experimental and theoretical work we show how to use the phototaxis properties of some micro-algae to modify and control the flow of a suspension of microswimmers.

CPP 35.2 Thu 15:30 C 243
Active viscosity of bacterial suspensions — •Anke Lindner, Jeremie Gachelin, Helene Berthet, Annie Rousselet, Gaston Mino, and Eric Clement — PMMH-ESPCI, 10, rue Vauquelin, 75231 Paris Cedex 05, France

Active suspensions are fluids laden with self-swimming entities such as bacteria, algae or artificial swimmers. The self-propelled particles inject energy into the suspending fluid, leading to very different properties of active compared to passive suspensions. In particular, it has been predicted theoretically that the viscosity of suspensions of so called pushers can be reduced compared to the viscosity of the suspending fluid.

Pioneering experimental measurements have confirmed that finding, but no bulk rheological experiments at controlled shear rates exist up to date. Here we present experiments measuring the viscosity of a wild type E-Coli suspension. To this purpose, we use a Y shaped microfluidic channel as a rheometer allowing us to resolve small differences between the viscosity of the suspending fluid and the active suspension at low shear rates and with a high resolution. We systematically vary the shear rate and the bacterial density. In this way we show that in a specific range of parameters the viscosity of the active suspension is lower than the viscosity of the suspending fluid. We discuss our results in the perspective of recent theoretical and experimental works .

CPP 35.3 Thu 15:45 C 243
Rheological properties of living and dead microalgae suspensions at various concentrations: the crossover between shear thinning and apparent yield stress behavior — •Antoine Soulies[1], Jack Legrand[1], Jeremy Pruvost[1], Cathy Castelain[2], and Teodor Burghelea[2] — [1]Universite de Nantes, CNRS, GEPEA UMR-CNRS 6144, Bd de l'Universite, CRTT-BP 406, 44602 Saint-Nazaire Cedex, France — [2]Universite de Nantes, CNRS, Laboratoire de Thermocinetique de Nantes, UMR 6607, La Chantrerie, Rue Christian Pauc, B.P. 50609, F-44306 Nantes Cedex 3, France

A systematic study of the rheological properties of solutions of microalgae suspensions (Chlorella) in a wide range of volume fractions is presented. At low volume fractions the suspensions display a Newtonian behavior and the volume fraction dependence of the viscosity can be well described by the Quemada model (Quemada 2006). For intermediate values of the volume fraction a shear thinning behavior is observed and the volume fraction dependence of the viscosity can be described by the Simha model (J. Appl. Phys, 23, 1952). For the largest volume fractions, an apparent yield stress behavior is observed. Increasing and decreasing stress ramps within this range of volume fractions indicate a thixotropic behavior. The rheological data acquired within the high concentration regime bears similarities with the measurements performed by Heymann et al. (Heymann et al. Phys. Rev E 75, 2007) on PMMA suspensions: irreversible flow behavior, dependence of the flow curve on the characteristic time of forcing. Solutions of dead microalgae generally behave similarly to that of living ones.

CPP 35.4 Thu 16:00 C 243
In situ large amplitude oscillatory shear (LAOS) experiments on rod-like viruses and colloidal platelets — •Pavlik Lettinga[1], Peter Holmqvist[1], Simon Rogers[1], Pierre Ballesta[1], Dina Kleshchenok[2], Bernd Struth[3], and Joachim Kohlbrecher[4] — [1]Forschungszentrum Jülich, Jülich,Germany — [2]van 't Hoff Laboratory, Utrecht University, The Netherlands — [3]Desy, Hamburg, Germany — [4]PSI, Villigen, Switserland

Highly anisotropic particles are by nature susceptible to external fields. In particular shear forces can cause a pronounced shear thinning, where a highly viscous unordered system is sheared into a low viscous ordered system. The rheological and structural responses of the system at the onset of shear thinning can be conveniently studied by large amplitude oscillatory shear in combination with in situ scattering techniques. Here we study two systems around the isotropic - nematic: dispersions of rod-like (fd) viruses in combination with time-resolved small-angle neutron scattering and dispersions of gibbsite platelets in combination with time-resolved small-angle X-ray scattering. Viewing the responses as indicating a sequence of physical processes, we identify, for the rod-dispersions, a region of purely elastic response accompanied by an increase in the orientational ordering. By yielding this is followed in sequence by a region of fluid-like behavior at an almost constant ordering. The platelet dispersions display, for a broad range of frequencies, a transition from singlet feature in the scattering at small strain amplitude to a doublet at large strain amplitude. This critical strain for reorienting the platelets is not reflected in the bulk rheology.

CPP 35.5 Thu 16:15 C 243
Nonlinear active micro-rheology of dense colloidal suspensions — •Thomas Voigtmann[1,2,3], Matthias Fuchs[1], Christian Harrer[1], and Manuel Gnann[1] — [1]Fachbereich Physik, Universität Konstanz — [2]Zukunftskolleg, Universität Konstanz — [3]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 51170 Köln

Active microrheology is a powerful tool to probe the local dynamics and rheological properties of a complex material, monitoring the response to external driving applied to a tracer particle. Especially the nonlinear-response regime reveals a wealth of information, but is less obvious to analyze than the linear response. We present recent advances in the framework of mode-coupling theory and the integration-through-transients formalism for force-driven microrheology, applying a constant force to a probe embedded in a dense, glass-forming colloidal suspension. A typical signature seen in experiment and computer simulation is a pronounced force-thinning, i.e., a strong reduction of the local friction at forces large compared to those induced by thermal fluctuations. We discuss this nonlinear effect in terms of a delocalization transition for the probe particle. We also address the limit of strong driving, where a non-trivial high-force plateau in the probe's friction coefficient is observed. Connections of these microscopic quantities to macroscopic rheological properties of the host liquid, and possible universalities among different system classes will also be discussed.

[1] I. Gazuz *et al.*, Phys. Rev. Lett. **102**, 248302 (2009).
[2] M. V. Gnann *et al.*, Soft Matter **7**, 1390 (2011).

CPP 35.6 Thu 16:30 C 243

Non-equilibrium Forces between Dragged Ultrasoft Colloids
— •Sunil P. Singh, Roland G. Winkler, and Gerhard Gompper — Institute of Complex Systems and Institute for Advanced Simulation,Forschungszentrum Juelich, 52425 Juelich, Germany

Ultrasoft colloids, such as, star polymers, in a suspension strongly interacted with each other under non-equilibrium conditions. Contact of two soft colloidal macromolecules may lead to large conformational changes and significant frictional forces, which determine the macroscopic rheological properties of the fluid. To arrive at an understanding of the non-equilibrium dynamical properties of ultrasoft colloids, we numerically investigate the deformation as well as dynamic frictional forces when two star polymers dragged past each other at constant velocity. We apply a hybrid simulation approach combining with multiparticle collision dynamics method for the solvent, with molecular dynamics simulations for the star polymers. We compute the dynamical frictional forces as function of the drag velocity. At vanishing relative velocity, the equilibrium repulsive force-distance curve is obtained. With increasing drag velocity, this behavior changes and we find an apparent attractive force for departing stars along the dragging direction. The close encounter of ultrasoft colloids leads to significant deformations. This behavior can be traced back to the retardation of polymer relaxation and symmetry breaking of the polymer conformations relative to the mid-plane between the polymer centers.

15 min break

CPP 35.7 Thu 17:00 C 243

Direct observation of translation and rotation of aggregated colloids under mechanical load
— •Jennifer Wenzl, Marcel Roth, and Günter K. Auernhammer — Max Planck Institute for Polymer Research, Mainz, Germany

The correlation between single particle interactions and meso- or macroscopic behavior of colloidal and granular matter is still not well understood. The challenge in 3D systems is to measure deformation, translation, and especially rotation of particles and agglomerates. Using confocal microscopy to obtain time resolved 3D imaging we track the particle positions. Introducing internal optical anisotropy allows us additionally to measure the rotation of spherical particles without changing their interaction. From the measured data we determine for every labeled particle both rotation angles. Combining mechanical load with simultaneous 3D microscopic imaging we explore the correlation between local structure, translation and rotation of the particles and the overall deformation of the system.

CPP 35.8 Thu 17:15 C 243

Transient rheology of concentrated suspensions
— •Miriam Siebenbürger[1], Thomas Voigtmann[2,3,4], Christian Amann[2], Matthias Fuchs[2], and Matthias Ballauff[1] — [1]Institut für Weiche Materie und Funktionale Materialien, Helmholtz Zentrum Berlin für Materialien und Energie, Berlin, Deutschland — [2]Fachbereich Physik, Universität Konstanz, Konstanz, Deutschland — [3]Zukunftskolleg, Universität Konstanz, Konstanz, Germany — [4]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Köln, Deutschland

Suspensions of sherical thermosensitive core-shell colloids are excellent model system for the study of the fluid to glass transition. In the last years the phase behavior, the linear [1] and nonlinear [2] viscoelastic properties as well as the rheological properties in stationary flow could be described in detail with the Mode Coupling Theory (MCT). Here we report on the transient rheology of these suspensions: i) For the start-up of shear aging-dependent overshoot phenomena are observed experimentally. The overshoot was also found by simulations [3] and can be described by a new schematic MCT-model. ii) The stress relaxation after switching off steady shear was found to be sensitive for the onset of the glassy state. iii) Finally, we present a systematic investigation of the creep behavior of the suspension in the glassy state.

References:
[1] M. Siebenbürger et al., J. Rheol. 53, 707 (2009).
[2] J. M. Brader et al., Phys. Rev. E 82, 061401 (2010).
[3] J. Zausch et al., J. Phys. Condens. Mat. 20, 404210 (2008).

CPP 35.9 Thu 17:30 C 243

Rheological Distinction between Gels and Soft Glasses during Critical Slowdown of their Relaxation Dynamics
— •Horst Henning Winter — National Science Foundation, Arlington VA, USA, and University of Massachusetts Amherst MA, USA

Gels and soft glasses are difficult to distinguish rheologically because both show a critical slow down in the approach of the liquid-to-solid transition. The dynamics is dominated by the diverging, longest relaxation time, tau,max, which assumes a noticeably large values and is hard to measure because of that. The difference between gels and soft glasses, however, becomes apparent in the distinct pattern of the relaxation spectrum of the critical slowdown. While the long-time component of the relaxation time spectrum follows a powerlaw in relaxation time for both, log H˜n log tau, their powerlaw exponent n is of different sign: negative n for the critical gel(material at the gel point) (Chambon et al. Polym Bull 13:499,1885; Winter et al. J Rheology 30:367, 1986; Chambon et al. J Rheol 31:683,1987) and positive n for the soft glass (Siebenbürger et al. J Rheology 53:707,2009; Winter et al. Rheol Acta 48:747, 2009).The powerlaw spectrum is cut off by the diverging, longest relaxation time (called alpha relaxation time for the soft glass, tau,max=tau,alpha) in the approach of the liquid-to-solid transition. In summary, patterns in the relaxation data provide a clear distinction between these two classes of materials.

CPP 35.10 Thu 17:45 C 243

Thermal convection in a nonlinear non-Newtonian magnetic fluid
— David Laroze[1,2] and •Harald Pleiner[1] — [1]Max Planck Institute for Polymer Research, Mainz — [2]Instituto de Alto Investigacion, Universidad de Tarapaca, Arica, Chile

We report theoretical and numerical results on the convection of a magnetic fluid in a viscoelastic carrier liquid. The non-Newtonian material properties are taken care of by a general hydrodynamic nonlinear viscoelastic model [1] that contains, but is more general than the standard Oldroyd and Giesekus phenomenological rheological equation for the stress tensor. We calculate the linear threshold for both idealized and rigid boundary conditions and make the comparison with the linear Oldroyd magnetic fluid [2]. In order to explore the nonlinear behavior we perform a truncated Galerkin expansion obtaining a generalized Lorenz system. We find numerically the system's stationary, periodic and chaotic regimes. Finally, we give a phase diagram depicting the various types of dynamical behavior as a function of the Rayleigh number and the viscoelastic material parameters.

[1] H. Pleiner, M. Liu, H.R. Brand, Rheol. Acta. 43, 502 (2004).
[2] L.M. Pérez, J. Bragard, D. Laroze, J. Martinez-Mardones, H. Pleiner, J. Mag. Mag. Mat. 323, 691 (2011).

CPP 35.11 Thu 18:00 C 243

Two-dimensional microrheology of freely-suspended liquid crystal films
— •Alexey Eremin, Sebastian Baumgarten, Sarah Dölle, and Ralf Stannarius — Otto-von-Guericke Universität, IEP/ANP, 39106 Magdeburg

It is well known that the hydrodynamic modeling of flow in two dimensional (2D) systems poses special problems that can be more complex than the three-dimensional counterparts, e.g. Stokes* paradox for the motion of disks in a 2D liquid membrane. Flow phenomena in restricted geometries have been intensively studied in the last years with implications to different physical, chemical and biological systems. Those studies usually employ indirect measurements of the inclusion mobilities, for the lack of a convenient 2D model system. On the other hand, smectic liquid crystals can form freely-suspended films of uniform structure and thickness, making them ideal systems for studies of 2D hydrodynamics. We have measured particle mobility and shear viscosity by direct observation of the gravitational drift of silica spheres, droplets and smectic islands included in these fluid membranes. In thick films, we observe a hydrodynamic regime dominated by lateral confinement, with the mobility of the inclusion determined predominantly by coupling of the fluid flow to the fixed boundaries of the film. In thin films, the mobility of inclusions is governed primarily by coupling of the film fluid to the surrounding air, as predicted by Saffman-Delbrück theory. A crossover between both regimes is observed.

CPP 35.12 Thu 18:15 C 243

Ermittlung der Axialkraft während der kapillaren Verjüngung von Fluidfäden (CaBER- Methode)
— •Dirk Sachsenheimer, Bernhard Hochstein, Hans Buggisch und Norbert Willenbacher — Karlsruher Institut für Technologie, Institut für Mechanische Verfahrenstechnik und Mechanik, Karlsruhe, Deutschland

Die Capillary Breakup Extensional Rheometry (CaBER) ist eine vielseitig anwendbare Methode zur Charakterisierung der Dehnviskosität niedrigviskoser, komplexer Fluide. Im Gegensatz zu anderen Messverfahren können sehr große, praxisrelevante Gesamtdehnungen erreicht werden. Die Bestimmung der Dehnviskosität ist jedoch eingeschränkt, weil die Zugkraft am Fluidfaden bisher nicht erfasst wird. Wir der Fluidfaden im Gegensatz zu dem herkömmlichen CaBER-Experiment nicht senkrecht, sondern horizontal verstreckt, so ermöglicht die Durchbiegung des Fadens die Berechnung der Axialkraft. Mit Hilfe dieser neuartigen Versuchsführung kann experimentell gezeigt werden, dass die Annahme der verschwindenden axiale Normalspannung für viskoelastische Fluide, die im CaBER-Experiment zylindrische, sowie mit der Zeit exponentiell abfallende Fäden bilden, im Rahmen der Messgenauigkeit gerechtfertigt ist. Im Gegensatz hierzu zeigen Newtonsche Fluide eine stärkere Durchbiegung. Diese ist auf eine negative axiale Normalspannung zurückzuführen. Mittels der experimentell bestimmten Kraft, sowie der zeitlichen Abnahme des Fadendurchmessers kann die wahre Dehnviskosität berechnet werden. Für Newtonsche Fluide ist diese erwartungsgemäß das Dreifache der Scherviskosität. Für viskoelastische Fluide wird ein deutlich größeres Verhältnis ermittelt.

CPP 35.13 Thu 18:30 C 243

Rheology of human blood plasma: Viscoelastic versus Newtonian behaviour — •Matthias Brust[1], Christof Schaefer[1], Roland Doerr[1], Paulo Arratia[2], and Christian Wagner[1] — [1]Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany — [2]Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, USA

We investigated the rheological characteristics of human blood plasma using three different flow experiments, namely the capillary breakup extensional rheometer (CaBER), a commercial rotational shear rheometer, and the shear flow in a contraction microfluidics. While the shear experiments showed a Newtonian behaviour, we found a viscoelastic behaviour of blood plasma in the pure extensional experiment. Comparing the results with those of a low concentrated polymeric fluid (PEO) with matchable rheometric characteristics in terms of elongational relaxation time and shear viscosity showed a consistent picture in all experiments. The results are discussed with regard to their relevance concerning venous blood flow in the human body.