CPP 61: Focus: Disordered Systems, Glasses under Shear I (joint session CPP, DY)

Time: Thursday 9:30–13:00 Location: C 243

Invited Talk CPP 61.1 Thu 9:30 C 243

Flow instabilities in soft glassy materials — •Suzanne Fielding — Department of Physics, Durham University, UK

Many soft materials, including dense emulsions, microgel suspensions, star polymers, onion surfactants, and textured morphologies of liquid crystals, share underlying glassy features of structural disorder and metastability. These give rise to several notable features in the low frequency rheology of these materials: for example, the existence of a yield stress below which the material behaves like a solid, and above which it flows like a liquid. Experiments have also revealed that these materials often display a phenomenon known as shear banding, in which the flow profile across the shear cell exhibits macroscopic bands of different viscosity. Two distinct classes of yield stress fluid have been identified: those in which the shear bands apparently persist permanently (for as long as the flow is applied), and those in which banding arises only transiently during a process in which a steady flowing state is established out of an initial rest state (eg in shear startup or step stress). After surveying this motivating experimental data, we describe recent progress in addressing it theoretically, using the soft glassy rheology model and a simple fluidity model. Time permitting we shall also discuss failure modes of these "soft glassy materials" in free-surface extensional flows.

CPP 61.2 Thu 10:00 C 243

Shear cessation in a Brownian-dynamics simulation for 2D hard disks — •Sebastian Fritschi and Matthias Fuchs — Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

We present results from a Brownian-dynamics computer simulation for the nonequilibrium transient dynamics in a colloidal glass former after the cessation of shear flow. In the glass, persistent residual stresses are found that depend on the flow history. The partial decay of stresses from the steady state to this residual stress is governed by the previous shear rate. Using a glassy hard-disk system, we also link this macroscale dynamics to microscopic particle motion, monitoring the transient mean-squared displacement measured during the relaxation from the steady state. A flow-induced second plateau is found in the mean-squared displacement at long times.

CPP 61.3 Thu 10:15 C 243

Microrheology of a Two-Dimensional Driven Granular System — •Peidong Yu, Boris Eberhardt, Sebastian Pitikaris, and Matthias Sperl — Institut für Materialphysik im Weltraum, Deutches Zentrum für Luft- und Rahmfahrt, Köln, Deutschland

We study the motion of a tracer particle pulled inside a two-dimensional granular model system, where particle movements can be controlled and precisely tracked. We put such a system on a shaking table and apply vertical agitation as thermalization. We show how well the particles are themalized in the horizontal direction. We then drag a tracer particle through such a system with constant force or constant velocity. Effective viscosities with different parameters are measured. Different scenarios of shear thinning and shear thickening are observed. The underlying physics is discussed and compared with simulations and theories.

CPP 61.4 Thu 10:30 C 243

Potential energy landscape analysis of sheared glass-forming systems — •Markus Blank-Burian and Andreas Heuer — Institut für Physikalische Chemie, WWU Münster, Deutschland

We performed molecular dynamics simulations of small binary Lennard-Jones mixtures ($65 \leq N \leq 1040$) under constant shear rates and at a very low temperature ($T = 0.01$). The shearing is achieved by applying Lees-Edwards periodic boundary conditions to the system.

In previous work on unsheared systems it was shown, that most of the physical properties of macroscopic systems are already encoded in these small systems. The dynamics of these small systems can be described by a continous time random walk (CTRW) between minima of the potential energy landscape (PEL). Our focus now lies on comparing these results with the constantly sheared system.

For the analysis of the sheared system, we perform energy minimization using the strain as an additional variable. We then use this information to identify inherent structures (IS) from the trajectories. These IS turn out to have zero strain. Thus, they are comparable to the unsheared system. From the resulting statistical data we hope to gain a microscopic understanding of macrorheological phenomena like the initial stress overshoot as well as the shear thinning in the plastic flow regime.

Invited Talk CPP 61.5 Thu 10:45 C 243

Dense granular flow — •Annette Zippelius — Institut für Theo. Physik, Univ. Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

In the first part of the talk I will discuss a jamming scenario of frictional particles, which can be interpreted as a nonequilibrium first order phase transition (1). Results of numerical simulations will be presented and analyzed in the framework of a simple model which can account for both, the continuous frictionless case and the discontinuous frictional case. The most important features of the frictional phase diagram are reentrant behaviour and a critical jamming point at finite stress.

The second topic to be discussed are dynamical heterogeneities and scaling in a driven granular fluid as structural arrest is approached (2). Large scale simulations of 2d bidisperse granular fluids allow us to determine spatial correlations of slow particles via the four-point structure factor. As the fluid approaches structural arrest, scaling is shown to hold. Both the dynamic susceptibility as well as the dynamic correlation, evaluated at the alpha-relaxation time,can be fitted to a power law divergence at a critical packing fraction. The measured susceptibility widely exceeds the largest one previously observed for hard sphere 3d fluids. The clusters of slow particles are neither compact nor stringlike but fractal. The cluster size distrbution is shown to fall off algebraically as structural arrest is approached.

(1) M. Grob, C. Heussinger and A. Zippelius, Phys. Rev E 89, 050201 (R) (2014); (2) K. Avila, H. C. Castill, A. Fiege, K. Vollmayr-Lee and A.Zippelius, Phys. Rev. Lett. 113, 025701 (2014)

15 min. break

CPP 61.6 Thu 11:30 C 243

Transient Rheology of Colloidal Suspensions - Shear Reversal — •Miriam Siebenbürger[1], Fabian Frahsa[2], and Matthias Fuchs[2] — [1]Helmholtz Zentrum Berlin, Germany — [2]Universität Konstanz, Germany

At low deformations, colloidal glasses exhibit first a linear deformation, followed by a stress overshoot and the sheared steady state [1]. In this transition range from solid to fluid the reversal of the shear deformation can spend insights in the dynamics of the underlying structural transformations. Experimental investigations are performed by model suspension of thermo-sensitive colloids, consisting of a poly(styrene) core and a poly(N-isopropylacrylamide) shell. By a set of shear reversal experiments the aging effect often observed in experimental systems can be discussed separately from the structural transformations due to the shear. The height and the position of the minimum of the undershoots in the reversed shear flow is correlated with the deformation at the start of the shear reversal. All results for different shear rates and waiting times will be compared to the Mode Coupling Theory (MCT) and simulations, which show good agreement compared to the experimental results [2].

[1] C. P. Amann, F. Weysser, M. Fuchs, M. Siebenbürger, M. Krüger and M. Ballauff, J. Rheol. 57,149 (2012).

[2] F. Frahsa, A. Bhattacharjee, J. Horbach, M. Fuchs and T. Voigtmann, J. Chem. Phys. 138, 12A513 (2013).

CPP 61.7 Thu 11:45 C 243

Lattice Boltzmann Simulations of Glass Forming Liquids — •Simon Papenkort[1] and Thomas Voigtmann[1,2] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Köln — [2]Heinrich-Heine-Universität Düsseldorf

The rheology of complex fluids undergoing a glass transition, such as colloidal suspensions or granular media, is highly nonlinear. The interplay between slow structural dynamics on the microscopic scale and a mesoscopic flow field gives rise to non-Newtonian flow effects. Prominent examples are shear thinning, dynamic yield and residual stresses. In a confined flow geometry, the shear rates, and thereby the fluid properties, can vary considerably in space and time. Even long after the flow has stopped, the material properties are profoundly affected by residual stresses.

Starting from first principles, mode coupling theory of the glass transition is able to provide constitutive equations that describe the history effects determining the flow of glass-forming fluids. The Lattice Boltzmann method is a modern simulation scheme to solve the Navier-Stokes equations even for complex flow geometries. We introduce a new, modified LB model [1] which is able to include memory-integral effects in fluid-mechanics simulations and provides a link between both regimes.

We find the viscoelastic transient dynamics and the appearance of residual stresses after stopping the flow to depend sensitively on the chosen flow geometry.

[1] J. Chem. Phys. 140, 164507 (2014)

CPP 61.8 Thu 12:00 C 243

Shear bands at the Jamming Transition: The role of Weak Attractive Interactions — •Ehsan Irani[1], Pinaki Chaudhuri[2], and Claus Heussinger[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany — [2]Institute of Mathematical Sciences, Tamil Nadu, India

We study the rheology of a particulate sytem close to Jamming in the presence of weakly attractive interactions. Lees-Edwards boundary conditions are used to simulate a shear-controlled flow. In addition to Bagnold scaling at large shear rates, the attraction results in a finite yield stress in the limit of small shear rates. In the yield regime a fragile solid is formed and the rheology can be explained by a scaling argument that exploits the vicinity to the isostatic state. In the transition region the shear stress develops a minimum, which (in large enough systems) leads to the formation of persistent shear bands. These features are rationalized by a scenario that involves the competition between attraction-induced structure formation and its break-down because of shearing. Properties of shear bands are studied in order to reveal the physical mechanisms that underly the non-monotonic flow curve and the flow heterogenities in the transition region. This work may help to elucidate the origin of shear bands in different materials with finite and short-ranged attractive forces.

CPP 61.9 Thu 12:15 C 243

Influence of drops on particles under shear — •Laurent Gilson, Jennifer Wenzl, and Günter Auernhammer — Max Planck Institute for Polymer Research, Physics at Interfaces, Mainz

We will present shear zone formation in granulates with and without the influence of liquid droplets. 3D Laser Scanning Confocal Microscopy (LSCM) was used to image polydisperse spherical silica particles (7μm) during quasi-steady strain controlled shear experiments.A shear cell was formed using a fixed bottom plate and a nanoindenter tip [1]. This arrangement creates a strain-controlled shear cell without lateral walls. Samples consisted of polydisperse spherical silica particles suspended in an index matching liquid. Immiscible droplets were used as a second phase. Position and form of the droplets, as well as position and size of the particles were recorded simultaneously using a dual channel LSCM [1,2,3]. Multiple images were taken during shear. A complete record of individual particle and droplet movement during shear was extracted.

We will focus our presentation on the differences between particles attached to droplets and particles in bulk. We will discuss differences and common features, as well as compare the results to features commonly found in sheared granular matter.

[1] Wenzl, J., Seto, R., Roth, M., Butt, H.-J., Auernhammer, G., Granul. Matter, 15, 391-400 (2012). [2] Crocker, J.C., Grier, D.G, J. Colloid Interface Sci. 179(1), 298-310 (1996). [3] Roth, M., Schilde, C., Lellig, P., Kwade, A., Auernhammer, G., Eur. Phys. J. E, 35(11), 124 (2012)

CPP 61.10 Thu 12:30 C 243

Shear bands in a model glass former — •Gaurav Prakash Shrivastav[1], Pinaki Chaudhuri[2], and Jürgen Horbach[1] — [1]Institut für Theoretische Physik II - Soft Matter, Heinrich-Heine-Universität Düsseldorf, Germany — [2]The Institute of Mathematical Sciences, Chennai, India

We study the mechanical response of a binary Lennard-Jones mixture by shearing it below the glass transition temperature with a constant strain rate. The onset of flow is associated with an inhomogeneous flow pattern [1,2]. Highly mobile regions form a long-lived shear-band-like structure. Although the flow curve is monotonic and stress-strain response does not show any signature of a shear band, this heterogeneity is captured very well in the mean square displacement of particles. The width of the shear band grows diffusively with time. We find that shear bands are more pronounced in the cuboid boxes than in the cubic boxes. This can be explained by the quadrupolar structure of the local strain fields. To investigate the origin of shear bands we identify the local events that lead to their formation. We observe that these initial active spots are localized to one or two particles.

[1] P. Chaudhuri, J. Horbach, Phys. Rev. E **88**, 040301(R) (2013).
[2] P. Chaudhuri, J. Horbach, Phys. Rev. E **90**, 040301(R) (2014).

CPP 61.11 Thu 12:45 C 243

Creep deformation of glasses under shear stress, results from a schematic mode-coupling model — •Fabian Frahsa and Matthias Fuchs — Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

The viscoelasticity of dense colloidal dispersions causes creep deformation under constant stress. Creep provides insight in the slow structural dynamics and dissipative processes of glasses.

We present predictions for the stress-driven rheology of glass from a schematic model of the mode-coupling theory (MCT) and compare them with experiments of core-shell micro gels. The schematic model is motivated by the microscopic ITT-MCT approach to the stress response of flow-driven systems and covers incompressible and homogeneous flows neglecting hydrodynamic interactions.