DY 7: Granular Matter and Contact Dynamics

Time: Monday 10:00–12:45 Location: ZEU 147

DY 7.1 Mon 10:00 ZEU 147

Collective dipole reorganization in magnetostructures — •Wafflard Adrien, Vandewalle Nicolas, and Opsomer Eric — GRASP, Institut de Physique B5a, Université de Liège, Liège, BE

Playing with spherical neodymium magnets that you find in your favorite toy market is really addicting. By assuming they are uniformly magnetized, magnetic beads behave as point-like dipoles. For scientists, those inexpensive objects demonstrate how dipolar particles self-assemble into various structures ranging from 1D chains to 3D crystals. We show that magnetotubes and magnetocrystals can self-buckle, i.e. change their geometry, above a critical aspect ratio. The underlying dipolar ordering is found to exhibit a collective reorganization, altering the mechanical stability of the entire system. We identify the conditions in which these phenomena occur and conjecture that in chains, square or cubic magnetostructures, neighboring dipoles reorientate in order to form the longest possible chains. This suggests that a wide variety of magnetostructures, including well known stable structures, may collapse due to reorientation of dipoles.

DY 7.2 Mon 10:15 ZEU 147

How is the growth of ferromagnetic granular networks controlled by an orthogonal magnetic field? — Matthias Biersack[1], •Ali Lakkis[1], Oksana Bilous[2], Pedro A. Sanchez[2], Sofia S. Kantorovich[2], and Reinhard Richter[1] — [1]University of Bayreuth, Experimental Physics V, 95447 Bayreuth, Germany — [2]Computational and Soft Matter Physics, Faculty of Physics, University of Vienna, 1090 Vienna, Austria

We are exploring in experiments the aggregation process in a shaken granular mixture of glass and magnetized steel beads, occuring in a horizontal vessel after the shaking amplitude is suddenly decreased. Then the magnetized beads form a transient network that coarsens in time into compact clusters, following a viscoelastic phase separation [1]. A homogeneous magnetic field oriented in plane has been observed to "unknot" network structures orthogonal to the field [2]. Here we focus on the impact of a magnetic field B_z oriented orthogonally to the plain of the network. We measure the average number of neighbours $\bar{k}(t)$ and the efficiency $E(t)$ of the emerging networks. Both can be fitted by a logistic growth function for $B_z \in [0,2]\,\mathrm{mT}$, unveiling that its characteristic time τ increases by about ten. Our results demonstrate that via dipole-dipole repulsion the field reduces the mobility of isolated steel beads, thus hindering the growth of the networks. The experimental results are compared with those of numerical simulations.

[1] A. Kögel, et al. *Soft Matter*, 14 (2018) 1001.

[2] P. A. Sánchez, J. Miller, S. S. Kantorovich, R. Richter, *J. Magn. Magn. Mater*, 499 (2019) 166182.

DY 7.3 Mon 10:30 ZEU 147

Dynamic light scattering from single macroscopic particles — Lisa Künstler[1], Raphael Kessler[1], Matthias Sperl[1,2], and •Philip Born[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 51170, Köln, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, 50937, Köln, Germany

Here we present a methodology to extract information from the fluctuations in light scattered from moving single granular particles. We first describe the experimental setup and the associated theoretical framework required to isolate contributions to the intensity autocorrelation function emerging from translational and from rotational particle motion [1]. We subsequently present an approach to extract the angular velocity and the translational speed of the granular particles from the light scattering data. The approach is applied to a small ensemble of granular particles in an hour-glass-like experiment to determine the granular temperature with a dynamic light scattering measurement. The results indicate the next steps to be taken to eventually develop a thermometer for fluidized granular media based on dynamic light scattering.

[1] L. Dossow, R. Kessler, M. Sperl, & P. Born, Dynamic light scattering from single macroscopic particles. Applied Optics, 60(32), 10160-10167 (2021).

DY 7.4 Mon 10:45 ZEU 147

Shear jamming and free surface deformation enable reciprocal swimming in granular materials — •Hongyi Xiao, Achim Sack, and Thorsten Pöschel — Institute for Multiscale Simulations, Friedrich-Alexander-Universität Erlangen-Nürnberg, Cauerstraße 3, 91058 Erlangen, Germany

Swimming with reciprocal motion is desirable due to its simplicity, but it is prohibited in Newtonian fluids at low Reynolds number as stated by the scallop theorem. Such a constraint can be broken in fluids with complex rheology. In this study, we show that propulsion generation with reciprocal motion in granular materials is enabled by a prolonged hysteresis in the material response, which originates from a combination of jamming-induced material rigidity and plastic deformation of the free surface. Using both lab experiments and discrete element method simulations, a reciprocal swimmer mimicking a scallop was constructed and buried in a tank of polydisperse granular particles. The swimmer consists of two wings that open and close with geometrical and temporal symmetry. The resistive force, the swimmer's displacement, and the deformation of the free granular surface were measured. Results indicate that net propulsion force is generated when the swimmer is tethered, and net displacement is generated when the swimmer is released. Small amplitude oscillatory experiments confirm the existence of an elastic regime at small strains, and free surface deformation measurement reveals its influence at large strains. Furthermore, a secondary symmetry breaking mechanism due to a cooperative effect of the wings is also identified.

DY 7.5 Mon 11:00 ZEU 147

Phase space characterization of three-dimensional nucleation of glass spheres — •Frank Rietz[1,2] and Matthias Schröter[2] — [1]University of Magdeburg, Department of Nonlinear Phenomena — [2]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Göttingen

Packings of macroscopic spheres serve as a model system for studying atomic states. In many compactification protocols, the spheres do not form nuclei and remain in the state of random close packing. By cyclically shearing a packing of 50000 spheres, we can cross this boundary and observe a transition from a disordered to a crystallized state [1]. The three-dimensional temporal positions of the spheres are tracked by refractive index-matched scanning [2]. The description of disordered states and the nature of random close packing are open scientific problems. In our case, we describe the nucleation process by partitioning the packing into local groups of four touching spheres. These groups of spheres are tracked during the crystallization process and their contacts and relative orientation are recorded in a phase space diagram. By comparing the states before and after crystallization with the states that avoid crystallization, we show whether there are conditions under which the spheres statistically tend to crystallize.

[1] F. Rietz, C. Radin, H. L. Swinney, M. Schröter: Nucleation in sheared granular matter, Phys. Rev. Lett. 120, 055701 (2018)

[2] J. A. Dijksman, F. Rietz, K. A. Lőrincz, M. van Hecke, W. Losert: Refractive index matched scanning of dense granular materials, Rev. Sci. Instrum. 83, 011301 (2012)

15 min. break

DY 7.6 Mon 11:30 ZEU 147

Non-convex particles under shear in a split bottom cell — •Mahdieh Mohammadi[1], Ahmed Ashour[2], Dmitry Puzyrev[3], Torsten Trittel[3], and Ralf Stannarius[3] — [1]Technische Hochschule Brandenburg — [2]Future University of Egypt — [3]Otto-von-Guericke-Universität Magdeburg

We study dynamical features of surface flow in the top layer of a granular bed containing non-convex tetrapod and hexapod particles in a split-bottom shear cell. Different heights of granular beds were prepared and examined. Based on Particle Image Velocimetry and Particle Tracking Velocimetry, angular and radial displacements of particles on the surface of the ensemble were derived in dependence on the number of rotations of the bottom disk. Stereoscopic measurements of surface fluctuations of the bed during shearing turn out to be a key factor in this study to characterize heap and sink formation phenomena, which are related to the secondary flow of the grain ensembles in the bulk. We acknowledge support of DPG with project STA 425/40 and DLR with project EVA (50WM2048), and stimulating discussion

with K. Harth.

[1] Mahdieh Mohammadi, Dmitry Puzyrev, Torsten Trittel, and Ralf Stannarius, Phys. Rev. E 106, L052901 (2022).

DY 7.7 Mon 11:45 ZEU 147

Forces on obstacles suspended in flowing granular matter — •Jing Wang[1], Bo Fan[2], Tivadar Pongó[3], Tamás Börzsönyi[2], Raúl Cruz Hidalgo[3], and Ralf Stannarius[1] — [1]Institute of Physics, Otto von Guericke University Magdeburg, Magdeburg, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Budapest, Hungary — [3]Física y Matemática Aplicada, Facultad de Ciencias, Universidad de Navarra, Pamplona, Spain

We investigate the force on a spherical obstacle exerted by a flowing granular material. A sphere suspended in a discharging silo experiences mechanical forces both from the weight of the overlaying layers and from friction of the surrounding moving granular material. When the flow stops due to clogging of the silo, in experiments with hard frictional glass beads, the force on the obstacle remains exactly the same as during flow. In contrast, for nearly frictionless soft hydrogel particles the force decreased considerably after the flow stopped. The dependence of the total force on the obstacle diameter is qualitatively different for the two types of material: It grows quadratically with the sphere diameter of the obstacle for hydrogel spheres, while it grows much weaker, nearly linearly with the obstacle diameter, in a bed of hard frictional glass spheres.

DY 7.8 Mon 12:00 ZEU 147

Free cooling dynamics and energy partition in 3D granular gas mixtures — •Dmitry Puzyrev[1], Adrian Niemann[1], Kirsten Harth[2,3], Torsten Trittel[1], and Ralf Stannarius[1] — [1]Institute of Physics and MARS, Otto von Guericke University, 39106 Magdeburg — [2]Department of Engineering, TH Brandenburg, 14770 Brandenburg an der Havel — [3]MARS and MRTM, OVGU, 39106 Magdeburg

Granular gases are nonlinear systems that exhibit fascinating dynamical behavior far from equilibrium, including unusual cooling properties, clustering and violation of energy equipartition. Our study focuses on 3D microgravity experiments with dilute ensembles of rod-like particles and their mixtures. In drop tower experiments at ZARM, we studied granular cooling of mixtures of rods with two different diameters. The confirmation of Haff's equation [2] describing the energy decay is of particular interest. Experimental data analysis suggests different cooling rates, and the violation of energy equipartition between the rotational and translational degrees of freedom for the mixture components. Particle detection and tracking was performed with Machine Learning-aided approach [3]. The software will be available as a Python library that can be extended to other 3D and 2D particle tracking problems.

The authors acknowledge support from DLR in projects EVA (50WM2048) and VICKI (50WM2252).

References: [1] K. Harth et al., Phys. Rev. Lett., 120 (2018), 214301 [2] P. K. Haff, J. Fluid Mech., 134 (1983), 401-430 [3] Puzyrev et al., Microgravity Sci. Technol., 32 (2020), 897

DY 7.9 Mon 12:15 ZEU 147

Effect of particle size on the suction mechanism in granular grippers — •Angel Santarossa, Olfa D'Angelo, Achim Sack, and Thorsten Pöschel — Institute for Multiscale Simulation, Friedrich-Alexander Universität Erlangen-Nürnberg, Cauerstraße 3, 91058 Erlangen, Germany

Granular grippers are highly adaptable soft actuators able to grasp objects of different shapes and sizes. They consist of an elastic membrane partially filled with a granulate. Their operating principle relies on the reversible jamming transition of granular materials. The filled membrane can be deformed and reshaped when pressed onto an object. When the air within the membrane is evacuated, the granulate hardens, creating forces to hold and manipulate the object. Three mechanisms contribute to the holding force of granular grippers: frictional forces, geometrical constraints, and suction effects. Using X-ray computed tomography, we link the activation of suction to the size of the particles. We show that a gripper filled with small particles (average diameter $d \approx 0.12$ mm) conforms to a high degree around the object than with larger particles (average diameter $d \approx 4$ mm), thus enabling the formation of air-tight seals. When the gripper is pulled off, simulating the lifting of an object, vacuum pressure is generated in the sealed cavity at the interface gripper-object. If the particles are too large, the gripper does not conform tightly enough around the object, leaving gaps at the interface gripper-object. These gaps prevent the creation of sealed vacuum cavities between the object and the gripper, impeding the suction mechanism from operating.

DY 7.10 Mon 12:30 ZEU 147

Visualization of flow dynamics for Poly-dispersed dense granular suspension in various sections of pipe — •Himanshu P Patel and Günter K Auernhammer — Leibniz-Institut für Polymerforschung Dresden e. V., Hohe Straße 6, D-01069 Dresden, Germany

The study of flow dynamics in non-Newtonian media with polydispersed dense granular suspension, e.g., slurry, mud, concrete, still lacks quantification on the flow parameters linked to shear induced particle migration and insight about flow at center and at wall in closed pipes.

We developed transparent granular system that is a granular suspension of particles suspended in non-Newtonian media (particle volume fractions of 30% to 48%) [1]. The non-Newtonian granular system has yield stress and plastic viscosity and is well index matched. The rheological characteristics of the model system is tunable through its composition of additives.

We analyze gravity-assisted continuous flow of millimetric sized particles. We perform tracking of flow at different sections of pipe. The flow analysis revels understanding on the relaxation of such flow and the development of velocity profile within the length of pipe, we observe this using camera at entry and exit of pipe and later a 3D setup to observe flow at near end of pipe. This gives quantitative values into the particle migration to understand the effect of polydispersity and particle flow.

[1] Auernhammer, Günter K., et al., Materials & Design (2020):108673