Large deformations

GDR SLAMM workshop

18th of June 2021

8:40	introduction	
9:00	Anwesha Sarkar	Oral lubrication performance of microgels
10:00	François Boulogne	Friction and entrainment of foam on rough surfaces
10:20	Davoud Zare	Large deformation of soft materials: challenges in dairy industry
10:40	posters & discussions on Gather	
11:20	Caroline Crauste-Thibierge	Simultaneous memory effects in the stress and in the dielectric susceptibility of a stretched polymer glass
11:40	Jean-Baptiste Salmon	Mass transport in a drying confined drop of a charged colloidal dispersion
12:00	Wilbert Smit	Interplay between gelation and fatigue in colloidal gels
12:20	lunch break	
14:00	Jan Vermant	Advanced rheometric techniques under large or fast deformations
15:00	Carole-Ann Charles	Viscoelasticity and elastocapillarity effects in the impact of drops on a repellent surface
15:20	Julien Bauland	Distinctive yielding of dilute colloidal gel
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16:20	Serge Mora	The shape of hanging elastic cylinders
16:40	Virgile Thiévenaz	Pinch-off of viscoelastic particulate suspensions
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18:00	end	

Oral lubrication performance of microgels

Presented by: Anwesha Sarkar
Food Colloids and Bioprocessing group, School of Food Science and Nutrition, University of Leeds, UK

Measurement of lubrication in orally relevant soft sliding surfaces has emerged as a key paradigm in the biotribology field. Such oral contact surfaces include biomimetic tongue-palate, tongue-food [1,2] interfaces and is recently providing fundamental insights into the physics of oral processing and sensory perception. In particular, biocompatible microgels have been recently demonstrated to act as excellent lubricants in the oral tribological contacts, with applications in dry mouth therapies and designing fat mimetics [3]. Using a combination of experimental techniques and theoretical considerations, this talk will cover three case studies [3-6] on tribology of soft elastomeric biomimetic tongue surfaces (with different wetting properties and surface roughness) in the presence of biopolymeric microgels with well-defined deformability, composition, cross-linking densities and particle sizes. Some of these microgels show aqueous ball-bearing abilities depending upon their volume fraction [4]. A case study [5] will be presented on how these microgels can act as viscosity modifiers of the continuum, where the lubrication performance can be quantitatively described using the Newtonian plateau value (η_∞). Finally, research on development of novel 3D soft tribo-surfaces to emulate the highly sophisticated tongue surfaces engineered by the nature will be highlighted [6].

References

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Friction and entrainment of foam on rough surfaces

Boulogne, François and Marchand, Manon and Commereuc, Alexis and Restagno, Frédéric and Rio, Emmanuelle

Presented by: François Boulogne
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From our daily experience of entraining foam when getting out of our bath raises the question of role of foam flows on rough solids. Indeed, the flow and deposition of a complex fluids such as a foam, depends strongly on the surface roughness, but also on the material rheology. We demonstrated (Marchand et al, PRL, 2020) that the key parameter is the ratio of the roughness and the Plateau borders sizes, the junctions between soap films. For large values, the flow is located in the bulk whereas for small values, it occurs at interfaces for which we propose a description of the interfacial stress. We illustrated that our experimental conditions fit the case of edible foams interaction with tongue papillae, indicating how to control friction forces allows and mouthfeel. We also considered the velocity criterion for foam deposition leading to a non-trivial behavior with foam and surface properties, which is of interest for coating applications like textile softening.

Large deformation of soft materials: challenges in dairy industry

Presented by: Davoud Zare
Fonterra

Dairy science and technology has benefitted enormously from concepts, models and analytical techniques developed by soft matter scientists. For a better understanding of dairy products, it is necessary to look more closely into the complex and dynamic relationships between composition and structure, processes and the macroscopic properties of them.
Most of the dairy products experience small and large deformations during processing, packaging and transportation and shelf life and finally during oral processing. This has huge impact on their functionality, performance and nutritional properties.
While a lot of rheological investigation is mostly done in the small deformation range, I will try to provide examples of large deformation stresses that are experienced by some of our dairy products and common bottlenecks and challenges we are facing due to knowledge gap in this area.

Simultaneous memory effects in the stress and in the dielectric susceptibility of a stretched polymer glass

J. Hem, C. Crauste-Thibierge, F. Clément, D.R. Long, S. Ciliberto,

Presented by: Caroline Crauste-Thibierge
Laboratoire de Physique, UMR 5672, ENS de Lyon

We report experimental evidence that a polymer stretched at constant strain rate $\dot{\gamma}$ presents complex memory effects after that $\dot{\gamma}$ is set to zero at a specific strain λ_w for a duration t_w, ranging from 100s to 2.2×10^5s. When the strain rate is resumed, both the stress and the dielectric constant relax to the unperturbed state non monotonically. The relaxations depend on the observable, on λ_w and on t_w. Relaxation master curves are obtained by scaling the time and the amplitudes by $\ln(t_w)$. The dielectric evolution also captures the distribution of the relaxation times, so the results impose strong constraints on the relaxation models of polymers under stress and they can be useful for a better understanding of memory effects in other disorder materials.

Mass transport in a drying confined drop of a charged colloidal dispersion

Salmon, Jean-Baptiste

Presented by: Jean-Baptiste Salmon
LOF, UMR5258

We investigated the drying of droplets of charged silica dispersions confined between circular plates. In-situ measurements of concentration fields using Mach-Zehnder interferometry help us to study the mass transport during the drying dynamics. More precisely, we measured the collective diffusion coefficient of the dispersion over a wide volume fraction range (0.25-0.6) evidencing the important role played by the long-range repulsive interactions. We also developed an original setup to measure mechanical stresses induced by drying in such experiments. This setup shows that significant tensile stresses emerge for these charged dispersions, well before the colloid close packing, due to the formation of a repulsive glass at a volume fraction 0.33. These observations suggest that the description of diffusive mass transport for these soft solids could also include poro-elastic contributions.

Interplay between gelation and fatigue in colloidal gels

Wilbert Smit

Presented by: Wilbert Smit
ENS de Lyon

We study the influence of external shear applied concomitantly to the sol-gel transition of a suspension of colloidal silica particles. In practice, upon the addition of salt, the colloids aggregate and form a space-spanning network, while we impose large amplitude oscillations during twice the gelation time. At short times, we observe that the gelation process is faster for increasing shear amplitudes due to increased mobility of colloidal aggregates. Conversely, at longer times, gels formed under oscillations of large enough amplitude show a lower elasticity and a viscoelastic spectrum, whose viscous modulus increases at high frequencies. The newly formed network holds a glassy-like microstructure due to the growth of microfractures, as evidenced by optical imaging and small-angle X-ray scattering experiments. Our results show that the interplay between shear and gelation can be used to tune the microstructure and, therefore, the mechanical properties of colloidal gels.

Advanced rheometric techniques under large or fast deformations

Presented by: Jan Vermant
Department of Materials, ETH Zürich, Switzerland

When we subject soft materials to large or fast deformations, the rheological response will reflect the response over many time- and lengthscales. Rheological measurements typically present an averaged response, which is great when were trying to predict properties (we can neglect some details) but at the same time somewhat annoying as we may loose microstructural insight. In this talk I will discuss some approaches to use advanced rheological methods which help us interrogate the microstructural or micro-scale responses which underly the behaviour at large deformations. These methods include (orthogonal) superposition rheometry (2,3), stress jumps and high frequency rheometry (1). The underlying micro-structural responses can also be interrogated thanks to advances in confocal imaging (4,5). The majority of examples will come from the colloidal domain, with colloidal gels being one of the favorite materials.

References

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Viscoelasticity and elastocapillarity effects in the impact of drops on a repellent surface

Charles, Carole-Ann and Louhichi, Ameur and Ramos, Laurence and Ligoure, Christian

Presented by: Carole-Ann Charles
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We investigate freely expanding viscoelastic sheets produced by the impact of drops on a quartz plate covered with a thin layer of liquid nitrogen suppressing shear viscous dissipation. The time evolution of the sheet is recorded using high-speed cameras. The viscoelastic fluids are Maxwell fluids, with low elastic moduli and relaxation times varying over two orders of magnitude, giving access to a large spectrum of viscoelastic and elastocapillary effects. The maximal expansion of the sheets, and the time to reach this maximal expansion, are measured as a function of the impact velocity. By using a generalized damped harmonic oscillator model, we rationalize the role of capillarity, bulk elasticity, and viscous dissipation in the expansion dynamics. The spring constant is a combination of the surface tension and the bulk dynamic elastic modulus. The time-varying damping coefficient is associated to biaxial extensional viscous dissipation and proportional to the dynamic loss modulus.

Distinctive yielding of dilute colloidal gel

Bauland, Julien and Famelart, Marie-Hélène and Leocmach, Mathieu and Croguennec, Thomas

Presented by: Julien Bauland
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The main protein fraction of milk is composed of four proteins, namely the $\alpha s1$-, $\alpha s2$-, β- and κ-casein (≈ 20 kDa). They naturally complex minerals, forming colloidal structures called casein micelles ($\approx 1.3 \times 10^6$ kDa). Their colloidal stability arises from the κ-casein that protrudes in the aqueous phase, providing steric repulsions. Addition of a proteolytic enzyme that hydrolyses the protruding segment suppresses the colloidal stability and leads to aggregation and gelation. Here, we study the yielding of the enzymatic milk gel during stress sweep through the changes in viscoelastic moduli. We observe a 3-step yielding: both moduli show a softening followed by a hardening at intermediate stresses until the gel completely breaks. Such behavior has not been observed in simplified casein gel and does not fit the state of art simulations. Creep and fatigue experiments are also performed at stresses in the softening or hardening stage to discuss the mechanisms of the yielding process.

The shape of hanging elastic cylinders

Serge Mora, Edward Andò, Jean-Marc Fromental, Ty Phou, Yves Pomeau

Presented by: Serge Mora
LMGC UMR 5508 CNRS-Université de Montpellier

Deformations of heavy elastic cylinders with their axis in the direction of earth's gravity field are investigated. The specimens, made of polyacrylamide hydrogels, are attached from their top circular cross section to a rigid plate. An equilibrium configuration results from the interplay between gravity that tends to deform the cylinders downwards under their own weight, and elasticity that resists these distortions. The corresponding steady state exhibits fascinating shapes which are measured with lab-based micro-tomography. For any given initial radius to height ratio, the deformed cylinders are no longer axially symmetric beyond a critical value of a control parameter that depends on the volume force, the height and the elastic modulus: self-similar wrinkling hierarchies develop, and dimples appear at the bottom surface of the shallowest samples. We show that these patterns are the consequences of elastic instabilities.

Pinch-off of viscoelastic particulate suspensions

Thiévenaz, Virgile and Sauret, Alban

Presented by: Virgile Thiévenaz
University of California, Santa Barbara

The formation of drops of a complex fluid, for instance including dissolved polymers and/or solid particles, has practical implications in industrial and biophysical processes. We experimentally investigated the generation of drops of a viscoelastic suspension, made of non-Brownian spherical particles dispersed in a dilute polymer solution. Our experiments show that the particles primarily affect the initial Newtonian necking by increasing the fluid viscosity. In the viscoelastic regime, particles do not affect the thinning until the onset of the blistering instability, which they accelerate. We find that the transition from one regime to another, which corresponds to the coil-stretch transition of the polymer chains, strongly depends on the particle content. We show that particles increase the local deformation in the liquid phase, and we propose an expression for the local strain rate. This method could enable the precise measurement of local stresses in particulate suspensions.

Solvent-responsive bilayer film actuators from nanofibrillated cellulose

Lopes da Costa, Lisa and Moreau, Céline and Cathala, Bernard and Villares, Ana

Presented by: Lisa Lopes da Costa
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An actuator consists of an anisotropic material that shows a motion response to external stimuli as pH, light and chemicals. Nanofibrillated cellulose (NFC) is a great candidate for the elaboration of a versatile platform of innovative actuators thanks to their alcohol groups allowing the introduction of new functionalities and their great mechanical properties. In this work, we fabricated films of NFC showing reversible bending under solvent changes. Anisotropy was designed by the assembly of graded films containing one layer from pure uncharged NFC and another charged via carboxymethylation. Reversible mechanism is achieved due to the asymmetrical swelling of layers in the different solvents. Once immersed in water, films curled towards the uncharged layer within 30s. When dipped in ethanol or 2-propanol, films recovered their initial shape and even bent towards the other direction. This work demonstrates possible routes for the design of programmable materials from NFC.

Posters

Colloidal gels tearing themselves apart

Stefano Aime, Matteo Sabato, David A. Weitz

Presented by: Stefano Aime
C3M, UMR 7167, ESPCI Paris

We study the strain field surrounding the tip of a fracture propagating in a colloidal gel. We find an unusual behavior: once the crack nucleates, the gel tears itself apart, as a consequence of its internal tension.

Multi-scale characterization of the microscopic dynamics during non-linear oscillatory rheology experiments

Edera, Paolo and Giavazzi, Fabio and Zanchetta, Giuliano and Cerbino, Roberto

Presented by: Paolo Edera
Università degli Studi di Milano

Oscillatory shear tests are widely used to characterize the mechanical response of complex fluids, but their interpretation in the non-linear regime remains challenging and ambiguous. We introduce echo-DDM: Differential Dynamic Microscopy with an echo protocol to obtain an optical characterization of the microscopic dynamics in different types of complex fluids under shear. We first obtain a complete characterization of the mesoscopic deformation field. We then use echo-DDM to characterize the microscopic, irreversible rearrangements induced by the external perturbation. In yield stress fluids, we find that the macroscopic yield transition is accompanied by the onset of shear induced diffusion, with an anomalously strong dependence of the diffusivity on the amplitude of the applied strain. The proposed methodology is not based on particle tracking and provides a promising tool for the exploration of non-linear rheology world

Extensional Gravity Rheometry (EGR) for yield stress fluids

Geffrault, Anatole and Bessaies-Bey, Hela and Roussel, Nicolas and Coussot, Philippe

Presented by: Anatole Geffrault
Laboratoire Navier, UMR8205, Ecole des ponts, Université Gustave Eiffel, CNRS

To measure the extensional rheological properties of yield stress fluids, we developed a rheometrical approach based on the analysis of the deformations of a fluid extrudate flowing downwards and breaking in successive elongated drops due to gravity. Assuming the gradients of longitudinal velocity in radial planes are negligible, the local instantaneous strain rate and stress are deduced from the variations of the filament shape. A further analysis allows to identify the data for which pure elongational stress and strain rate components are dominant, so that the elongational flow curve of the material can be deduced. For an emulsion and a clay suspension, all the normal stress vs extensional rate data obtained under different flow conditions fall along a single master curve for each material. This flow curve in elongation is well represented by the standard 3D Herschel-Bulkley model. In particular, the elongational yield stress is very close to the simple shear yield stress times 3.

Nonlocality in the transient rheology of non-Brownian suspensions

Athani, Shivakumar and Metzger, Bloen and Forterre, Yoel and Mari, Romain

Presented by: Romain Mari
Univ. Grenoble-Alpes and CNRS, LIPhy

Dense non-Brownian suspensions are mixtures of micrometric particles and fluid, mixed in roughly equal proportions. They have a non-Newtonian rheology, albeit a simple one, as stresses are linear in the shear rate. While their steady rheology is well characterized, transient responses are still poorly unknown. In particular, an open problem is the extension of steady constitutive models, such as the mu(J) rheology, to unsteady conditions. In this work we develop Discrete Element Method simulations of dense non-Brownian suspensions sheared under varying imposed pressure. We show that a step change in applied pressure leads to non-trivial transient dilation dynamics. We then demonstrate that this dynamics can only be captured by a time-resolved extension of the mu(J) rheology including dilatancy. Interestingly, this rheology induces nonlocal stresses, with a nonlocality length scale which diverges at jamming.

Postitive feedback effects in 2D creeping flow of viscoelastic fluids through porous media amplify preferential flow paths

Mokhtari, Omar and Davit, Yohan

Presented by: Omar Mokhtari
Institut de mécanique des fluides de Toulouse

The flow of dilute polymer solution in model porous media consisting of an array of cylinder is considered. Numerical [1] and experimental [2] studies show that such flows are subject to the intensification of preferential flow paths. We seek to study the mechanisms of reinforcement of these preferential flow paths which are crucial to the understanding of these flows. We consider here the Oldroyd-B model of dilute polymer solutions. We show that the reinforcement mechanism of the preferential flow paths is linked to the appearance of elastic membranes which will interact with the flow. [1] S. De, J.A.M Kuipers, E.A.J.F Peters, and J.T Padding. Viscoelastic flow simulations in random porous media. Journal of Non-Newtonian Fluid Mechanics, 248 :5061, 2017. [2] D.M. Walkama, N. Waisbord, and J.S. Guasto. Disorder suppresses chaos in viscoelastic flows. Phys. Rev. Lett., 124 :164501, Apr 2020.

Direct Confocal Imaging of Fracture Precursors in Casein Gel

Singh,Akash and Tateno, Michio and Simon, Gilles and Vanel, Loic and Leocmach, Mathieu

Presented by: Akash Singh
ILM CNRS

Gels due to their heterogeneous nature, show a complex, yet characteristic delayed yielding behavior under the application of sub-critical stress. This makes us interested in understanding what are the signs or precursors existing within the material before the final catastrophic failure. Scattering studies hint toward microscopic changes well before failure. What we are interested in is the direct real-space observation of the gel microstructure under shear. For this, we have designed our own setup ICAMM, which can be integrated with a confocal microscope and has precision in stress application and measurement up to 3 mPa. This setup is integrated into a confocal microscope to have simultaneous shear experiments and 3D image acquisition. Using a 3D implementation of a dense optical flow algorithm on the confocal images of the sheared gel, we are able to obtain the local strain rate field and thus, detect and have statistics on structural precursors (strand breaking events).

Nonlinear shear flow of model entangled polymers: experiments and modeling

Hamid Taghipour, Christina Pyromali, Laurence Hawke, Dimitris Vlassopoulos and Evelyne Van Ruymbeke

Presented by: Hamid Taghipour
UCLouvain

We investigate, both theoretically and experimentally, the viscoelastic response of entangled linear polymers under fast shear flow, in order to identify the molecular origin of their steady shear thinning and their transient stress overshoot. To this end, we first perform the different tube-based models proposed in literature (i.e. the MLD, and the GLaMM models) and confront the predicted stress growth coefficient to recent experimental data for monodisperse linear polymer melts and solutions. This allows us to identify several issues, mainly related to the way the chain retraction induced by a high shear flow is taken into account in the models. We then propose a new approach, based on the idea of blobs in shear flow and implement in our TMA tube-based model, to predict the steady shear viscosity of these samples deformed at constant rate. The quantitative agreement found with the experimental data demonstrates the importance of linking constraint release effect and chain stretching.