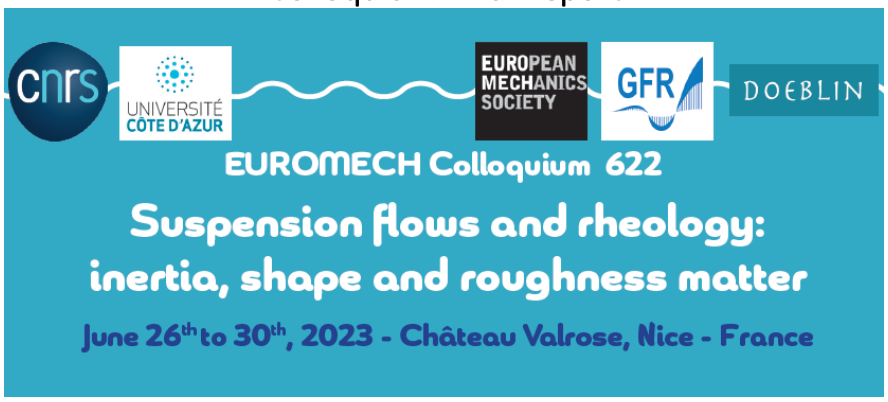
Colloquium Final Report



Chairpersons Elisabeth Lemaire (Nice, FR) – Eric Climent (Toulouse, FR)
Co-Chairpersons Micheline Abbas (Toulouse, FR) and Eric Keaveny (London, UK)

Purpose of the colloquium: Particle-laden flows span scales ranging from the microscopic fluid-structure interactions observed in cellular biology and microsystems, to the large-scale transport of sediments by turbulent environmental flows and engineering processes. The coupled dynamics of the continuous fluid phase and the particles has been a longstanding topic of research in physics and (mechanical, chemical, aerospace) engineering departments
Although particulate flows are involved in large scale applications, the complex nature of their behaviour originates at the particle length scale, making the characteristic Reynolds number to be small or moderate. At the scale of particles, many physical effects drive the response of the suspension including multi-body hydrodynamic interactions, lubrication and non-hydrodynamic effects such as friction and DLVO forces (repulsion or attraction). The very small particles also experiencing Brownian diffusion which couple with hydrodynamic interactions. The past 30 years have seen great progress in a diverse set of computational techniques, including LBM, IBM, FCM, DPD, SPH, SD and others, as well as the development of new experimental methods including local rheometry (X-ray, MRI, suspension imaging), controlled particle pressure measurements, microscopic contact law determination...
The purpose of this colloquium was to gather the leading experts in experimental and computational methods for low Reynolds number particulate flows to share the state-of-the-art progress and compare techniques and results.

Scientific TOPICS

- Low Reynolds suspensions: from single particle to collective behavior
- Particle migration
- Active suspensions
- Solid contact (roughness, friction, adhesion, rebound)
- Effect of particle shape
- Soft particles[1]
- Non-viscosimetric flows and Non-Newtonian fluids

[1]This session was not initially planned. However, we received several proposals for contributions on this topic while, at the same time, relatively few submissions concerned the topics “Non-Newtonian fluids” and “Non-viscosimetric flows”. We therefore decided to combine these two last topics and open a "Soft particles" session.

Conference fees

EARLY BIRD REGISTRATION

Faculty, Post-docs, Research fellows: 400 €

PhD and Master students: 250 €

FINAL DEADLINE FOR REGISTRATION

Faculty, Post-docs, Research fellows: 500 €

PhD and Master students: 300 €

What other funding was obtained? We have received financial support from

CNRS

Université Cote d'Azur

GFR

Fédération de recherche Doeblin

What were the participants offered? The registration fees included:

- The book of abstracts.
- 2 daily coffee breaks and 4 lunches + welcome cocktail with jazz band
- 1 gala dinner at restaurant Castel in Nice

Number of participants ~60

Faculty members: 33 + 9 invited speakers + 4 organizers

PhD students: 12

France	21
Netherlands	5
UK	5
USA	4
Italy	3
Germany	2
China	2
India	2
Poland	2
Japan	2
Luxemburg	1
Spain	1
Russia	1
Sweden	1
Greece	1

Scientifc report on all topics

Low Reynolds suspensions: from single particle to collective behavior - introduced by George Petekidis (Dept. of Materials Science & Technology, Univ. of Crete, Greece)

Tuning and training of colloidal gels by external fields: Inducing memory and manipulating properties

The collective dynamics of particle suspensions has been a longstanding topic of research and this workshop was intended to give new insights on experimental techniques, numerical simulations and theoretical modelling of new physical phenomena. Hydrodynamics at low Reynolds number is the backbone of the present symposium since most of studies deal with negligible (or low) effect of inertia. Specific methods have been presented for spherical, non-spherical and deformable particles including different aspects of short-range interactions such as physical-chemical forces, roughness or friction. In particular, small variations in physical-chemical properties (e.g. particle surface roughness, van der Waals forces) may result in drastic changes of the suspension dynamics such as particle migration together with aggregation, shear-thinning or discontinuous shear-thickening.

Particle migration – introduced by Ryohei Seto (Wenzhou Institute, China)
Pressure-driven flows of frictional dense suspensions: migration, jammed plug, and diffusion. Ganesh Subramanian (JNCASR, Bangalore, India) Rheology and dynamics of dilute inertial suspensions

Presentations on particle migration in suspension flows can be gathered in two groups. In the first group, the migration of particles in shear flow is associated with finite flow inertia and non-uniform velocity gradient at the particle scale. The presentations covered the evolution of theoretical / numerical tools to capture this phenomenon, the formation and stability of particle alignment along the flow direction (associated with dipolar and quadrupolar interactions respectively), the effect of confinement as well as the transition of orbits of non-spherical particles in shear flow at finite flow inertia and the subsequent impact on the flow rheology (at low particle concentration). In the second situation, particle migration is associated with high particle concentration (and eventually confinement, which corresponds to the particle size compared to the flow length scale). In that case, presentations tackled wide topics like local constitutive law in pressure-driven flows at low Reynolds numbers, the effect of friction on the migration, particle migration in tube flow across a wide range of concentrations and Reynolds numbers, the formation of giant vortices of micro-swimmers in confined domains.

Active suspensions - introduced by Corinna Maas (TNW, Univ. Twente, Netherlands)
Collective effects in active emulsions

This topic has been introduced by the keynote lecture of C. Maas on active emulsions. This has set a number of intriguing phenomena from the auto-propulsion of droplets to their collective dynamics and interactions with boundaries. Micro-rollers were another aspect of the emergence of coherent motion of propulsive particles. Experiments were analyzed under the light of numerical simulations and a theoretical prediction of instabilities yielding from deformation into autonomous group of moving particles. Studying active filaments is also a scientific field prone to interesting physical mechanisms. The synchronization of beating due to multi-body hydrodynamic interactions has been successfully reproduced by numerical simulations. Bacteria and other types of active cells have been placed in different flow configuration in order to assess their overall response to the flow in the dilute and concentrated regimes.

Solid contact (roughness, friction, adhesion, rebound) - introduced by Emmanuela del Gado (Georgetown Univ., USA) Flow induced rigidity percolation in shear thickening suspensions
Francesco Bonacci (Dipartimento di Fisica e Geologia, Università di Perugia, Italy)
Contact drives mechanical ageing in dense and attractive colloidal suspensions

Over the last ten years, it has been shown to what extent the rheology of suspensions, and more generally their dynamics, are affected by the presence of solid contacts between particles. In particular, the existence of frictional contacts between particles offers explanations for the non-Newtonian behaviors (shear thickening, shear thinning) observed in non-Brownian suspensions. Some experiments carried out at controlled particle pressure and that highlight the frictional character of suspensions were presented (Keynote lecture of Bloen Metzger). Several conferences focused on linking interparticle contact properties to the rheological properties of suspensions. In particular, a keynote lecture given by Francesco Bonacci showed that the thixotropy observed in some non-Brownian suspensions could be explained by contact aging. The keynote lecture of Emmanuela del Gado showed that frictional contacts play also a key role in the development of a very specific self-organization of suspension microstructure during Discontinuous Shear Thockening with the growth and percolation of constrained particle networks. An important conclusion of this session is that an accurate description of particle friction properties (rolling and sliding friction) is necessary to understand the flow properties of non-Brownian suspensions.

Effect of particle shape - introduced by Anke Lindner (PMMH, Paris, France)
Suspensions of elongated particles: from flexible fibers to bacteria

Presentations on the effect of particle shape included inputs from experiments as well as theories/computations. Some talks addressed theoretical calculation of the grand resistance tensors of a rigid body of a given shape at low Reynolds numbers. Many presentations showed results on the dynamics of elastic (flexible) filaments or sheets, varying the particle elasticity compared to the local viscous stress. The short-time and long-time dynamics of individual particles was investigated in shear flow. The influence of hydrodynamic interactions, the microscopic structure and rheology of the corresponding suspensions at non-negligible particle concentration were also discussed. Some presentations tackled the transport of particles in peculiar applications, like the flow of star-shape particles in the hopper that differs from the flow of spherical particles, as well as the transport of fibers in microfluidic three-dimensional vortices.

Soft particles - introduced by Simon Mendez (IMAG, Montpellier, France)
Simulation of flows of deformable red blood cells: a challenge in modeling, numerics and physics

The effect of particle rigidity on the rheology of particle or vesicle suspensions is currently a very active topic. These suspensions of soft objects are present in many industrial applications and in natural flows such as blood, which are very important to model. This session was introduced by Simon Mendez's plenary lecture on the modeling of a suspension of red blood cells. Other talks featured original rheology experiments (resuspension, constriction flow) on suspensions of soft particles or capsules.

Non-viscosimetric flows and non-Newtonian fluids - introduced by Bloen Metzger (IUSTI, Marseille, France)

A new osmotic-like rheometer reveals the dual rheology of shear thickening suspensions

Particulate flows at vanishing Reynolds number in viscosimetric flows are now fairly well known but particle transport and suspension rheological properties are far from being understood for more complex flows. In this session, quite complex flows were tackled. We attended talks about the behaviors of spherical particles and fibers suspended either in a Newtonian or a slightly elastic fluid in a vortex flow field. The case of concentrated suspensions under shear rotation was discussed - experimentally, numerically and theoretically. The case of suspensions subjected to extensional flow was also addressed with some applications to the description of polymeric chains flow.

Group Photo