EUROPEAN MECHANICS SOCIETY

Colloquium Final Report

N. 628 – Complex particles in turbulent flow

Dates and location: **03/05/2023 - 05/05/2023, Nice, France**

Chairperson **Dario Vincenzi**

Co-Chairperson **Andrea Mazzino and Rama Govindarajan**

Conference fees

- Regular registration **0.0 €**

What other funding was obtained? **We have received additional financial support from the French Agence Nationale de la Recherche (ANR) and the Academy of Complex Systems of Université Côte d'Azur (IDEX UCA JEDI).**

What were the participants offered? **The participants were offered a welcome buffet before the opening session, 1 aperitif in the evening of the second day, 2 lunches, 4 coffee breaks.**

Number of members of Euromech (reduced registration fee) **42**

Number of non-members of Euromech (full registration fee) **0**

Applicants (members)

- Gholamhossein Bagheri
- Jeremie Bec
- Stefano Berti
- Guido Boffetta
- Mireille Bossy
- Luca Brandt
- Christophe Brouzet
- Carlo Massimo Casciola
- Massimo Cencini
- Filippo Coletti
- Elisabetta De Angelis
- Mees Flapper
- Fabiola Antonietta Gerosa
- Lucas Gey
- Jean-Baptiste Gorce
- Horia Hangan
- Christophe Henry
- Eric Ibarra
- Sardor Israilov

- Linfeng Jiang
- Gregory Lecrivain
- Cristian Marchioli
- Andrea Mazzino
- Selim Mecanna
- Valentin Mouet
- Aurore Naso
- Vikash Pandey
- Pijush Patra
- Stéphane Perrard
- Giulia Piumini
- Hélène Politano
- Hugo Poncelet
- Leonardo Puggioni
- Florence Raynal
- Aliénor Rivière
- Francois Schmitt
- Agnese Seminara
- Jan Siemen Smink
- Duco van Buuren
- Robert Van Gorder
- Gautier Verhille
- Dario Vincenzi

Scientific Report

Understanding particle dynamics in turbulence is relevant to mixing, combustion, and environmental pollution. The study of transport by turbulent flows has benefited greatly from the development of new experimental, numerical, and theoretical Lagrangian techniques. These have made it possible to investigate the statistics of the velocity, the acceleration, and the dispersion of both tracer and inertial particles. While the early Lagrangian studies were mainly concerned with the motion of point particles, in recent years the study of particle dynamics in turbulent flows has extended in several new directions.

Microscopic complex particles, while still moving with the fluid, possess additional degrees of freedom. Several studies have thus investigated the orientation and rotation of anisotropic solid particles (such as small rigid fibres or ice crystals), the stretching of elastic polymers, the bending and fragmentation of small flexible fibres. Complex-shape particles such as crosses, jacks, and helicoids have also been used to gain information on the local properties of the turbulent velocity field.

The study of macroscopic objects (with sizes in the inertial range or even exceeding the velocity integral scale) is a very challenging problem. Indeed, while sub-Kolmogorov, inertialess objects follow fluid trajectories and their orientation and deformation are fully determined by the local velocity gradient, a finite-size object samples multiple scales of the flow. If in addition the object is deformable, its conformation is strongly coupled with its displacement, further complicating its dynamics. The importance of such aspects is well known for filaments in quiescent and creeping flows. In turbulence, they have only recently begun to be studied in the case of long fibres.

Moving beyond single-particle dynamics, many important questions regarding the dynamics of ensembles of complex particles remain unexplored. The formation of clusters and the collisions between particles are indeed influenced by their shape and deformability. Moreover, complex particles may even assemble and possibly tie up to macroscopic aggregates which in turn can modify the carrier turbulent flow.

The dynamics of active particles, such as swimming bacteria, plankton, or

anguilliform juvenile fishes, has also attracted much attention in recent years. The focus has been on how the orientation and deformation dynamics of such self-propelled particles interferes with the carrier turbulent flow. Another interesting question is how particle motility can possibly lead to the formation of “active” aggregates.

The EUROMECH Colloquium 628 aimed at discussing recent advances and open questions around complex particle dynamics in turbulent flows by gathering scientists from both the physics and engineering communities.
The programme of the meeting comprised 37 presentations, divided as follows: 7 invited lectures, 23 contributed talks, and 7 short presentations associated with posters. There were 42 participants from 9 different countries. The result was a nice combination of presentations from both young and senior researchers, with contributions on experiments, numerical simulations, and modelling. The programme of the meeting was enhanced by a few interdisciplinary presentations on atmospheric, astrophysical, and biological applications.

The programme and the book of abstracts is available on the website of the Colloquium. A summary of the scientific problems discussed at the meeting follows.

– Microscopic complex particles were naturally one of the main topics of the meeting. The talks in this area covered the resuspension of glass particles by a turbulent gas flow, the design and production of microfibres for experimental studies of particle laden turbulence, the turbulent dynamics of suspensions of chiral particles, as well as experimental techniques for tracking such particles. Solutions of polymers (rigid or elastic) were also part of the programme: numerical results were presented on both turbulent drag reduction at high Reynolds numbers and mixing enhancement at low Reynolds numbers. The effect of an external field on particle dynamics was discussed in the context of the convective transport of phytoplankton. Its survival and growth indeed depends on the distribution of the light intensity at the surface.

– Another important topic of the meeting was the dynamics of macroscopic particles. Ample space was naturally given to the study of long fibres. Various aspects of fibre dynamics were discussed: transport, deformation, orientation, and rotation (spinning and tumbling). Both experimental and numerical studies were presented. It was also shown that fibres can be employed to measure the statistics of the velocity fluctuations in an efficient way. Other macroscopic particles that were considered at the meeting includes rigid spherical particles (with a focus on their modulation of turbulence) and thin disks (namely, their trapping near to a vortex).

– Some talks considered point-like particle dynamics. An invited lecture introduced the topic by presenting recent results on particles floating on a free-surface flow in a set of different experimental facilities. The statistics of particle dynamics was analysed, and it was shown that compressibility effects lead to the formation of aggregates. These issues are particularly relevant to marine plastic pollution. The effect of an imposed mean solute gradient on the dispersion of phoretic particles was also discussed at the meeting. Both theoretical results in a cellular flow and experiments in a salty solution confined in a Rayleigh–Bénard cell were presented. A few talks then focused on the effect of inertia on particle dynamics. In particular, it was shown that a turbulent mixing layer forms at the interface between a dilute suspension of heavy particles and a pure fluid lying below it. It was also discussed how the velocity fluctuations impact the distance travelled by droplets injected in a turbulent boundary layer. In the context of astrophysical flows, one of the talks

examined the clustering of inertial particles in protoplanetary disks and its dependence on the flow rotation and the particle size.

– Turbulence in clouds attracted significant attention. One invited lecture reviewed recent results on topics related to the dynamics of anisotropic particles and its applications to cloud microphysics, namely the effect of inertia on settling, the dependence of the orientation statistics on the particle shape, the collisional dynamics and the growth of ice crystals. A contributed talk provided additional analytical results on the collision of sedimenting particles and on droplet growth in clouds. The second invited lecture on this topic presented measurements of the droplet size distribution in shallow cumulus clouds. These measurements were obtained during a recent campaign over the Atlantic Ocean near Barbados. A talk was also given on a method based on unsupervised machine learning for classifying real precipitation conditions and thus identifying critical parameters of precipitation particulates.

– A certain number of talks were concerned with turbulent bubbly flows. The statistical properties of the velocity in buoyancy-driven bubble-laden flows were discussed in detail, as was the shape statistics of bubbles and its dependence on the flow properties. A torque reduction was also reported for high air volume fractions in a von Kármán flow. In addition, multiphase flow simulations were presented that described the impact of turbulence on the collision efficiency between bubbles and heavy particles.

– The meeting comprised contributions on active or swimming particles. One point common to some of these contributions was the use of machine learning techniques to understand the swimming dynamics of fish and its navigation strategy through a turbulent environment, as well as the evolution of a prey–predator system of micro-swimmers in a hydrodynamic environment. An experimental study of the dynamics of copepods was also presented, with a focus on the effect of turbulent fluctuations on the formation of long chains.

– Finally, general issues on hydrodynamics were also discussed, such as the effect of a flow on the formation of Turing patterns in chemical systems, a new forcing technique for generating isotropic turbulence that used the erratic motion of magnets, and the design of a jet grid for the study of high-Reynolds-numbers multiphase flows in a water tunnel.

Number of participants from each country

Country	Participants
France	21
Italy	8
Netherlands	5
Sweden	2
Germany	2
New Zealand	1
Switzerland	1
Canada	1
India	1
Total	**42**

Please send this report in electronic form to the Secretary General of EUROMECH, within one month after your Colloquium.