EUROMECH Colloquium 588

"Coupling Mechanisms and Multi-Scaling in Granular-Fluid Flows"
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Granular flows are encountered in many geophysical and industrial applications. The transport of sand in rivers, oceans, deserts and oil pipes, debris flows and snow avalanches are some examples where the dynamics of the flow are controlled by the physical processes induced at the grain scale. Contrary to classical fluids, the size of the elementary constituents of granular materials is not infinitesimal with respect to the mesoscopic deformation scale, such as the length of ripples and dunes in sediment transport or run-out in avalanches, which makes their continuous description questionable. Yet, in the case of dry granular flows for which the effect of the surrounding fluid can be neglected, phenomenological rheological models and more fundamental approaches based on kinetic theory have been developed during recent decades and have been shown to be relevant in many situations. When interactions with the fluid are significant, the problem becomes more complex as the fluid can flow in the granular medium, leading to strongly coupled dynamics between the two phases. Extending continuous models towards such configurations and thus modelling granular fluid flows at the different scales remain a challenging task. The description of granular-fluid dynamics has been an increasingly attractive field of research for the last ten years, leading to a substantial stream of publications, including field measurements as well as laboratory experiments, numerical modelling at various scales and theoretical developments.
The aim of EOROMECH Colloquium 588 was to gather the European scientific community to exchange on recent developments regarding the coupling mechanisms in granular fluid flow at all scales, from that of the grain to that of the whole system.
The main topics were:

- Macro-phenomena: bedload and saltation; collisional suspensions; turbulent suspensions; debris flows and granular-fluid avalanches.
- Micro-processes: turbulence modulation; relaxation processes; rheology; boundary conditions.

Colloquium 588 was held from the 2 to 5 October 2017 at the Institut de Mécanique des Fluides de Toulouse. There were more than 50 participants and 41 presentations including 4 keynote lectures given by Olivier Pouliquen, Marseille; Jim McElwaine, Durham; Jim Jenkins, Cornell University, Ithaca, USA; and Eric Lajeunesse, Paris. Each day was dedicated to a specific scientific topic, introduced by one of the keynote lectures. Scientific issues addressed and discussed during these days were:

- **Fluid-particle interaction and rheology**

The modelling of fluid-particle flows encountered in applications remains a key issue. Continuum models need constitutive equations to describe the coupled system. These rheological models should work for situations as complex as the ones observed in nature, involving irregular particle shapes and unsteady, inhomogeneous flow configurations. On the other hand, discrete numerical simulations, such as DNS for the fluid coupled with DEM for the particles, which could be used to test the continuum, rheological models, need to account for the local interaction/contact between particles. As the scale of this interaction is small compared to the size of the system, this short-range modelling remains challenging, in particular when particle shape is complex, while being a key ingredient for continuum models in dense configurations. The presentations proposed during the first day of the colloquium highlighted the new results obtained on these issues. In particular, they showed results on models for the rheology of suspensions of solid particles as complex as fibres, the role of turbulence on the rheology, the influence of surface roughness and shape on the local particle-particle interaction, the integration of lubrication models into DNS simulations at the micro-scale. An important data set obtained from idealized experimental configurations has been shown to be available to support rheological models, which can now be included in numerical models resolved at the scale of the particles. This will allow major progress in the parametrization of large scale models to predict more complex flows.

- **Granular avalanches**

Most avalanches and landslides observed at the surface of the Earth can be modelled as granular flows interacting with a surrounding ambient fluid. The community is seeking a closer collaboration between field measurements and idealised laboratory experiments/simulations. The keynote of this session was focused on field observations and key questions associated with these observations. Laboratory experiments and numerical modelling showed in the different presentations focussed on some of these questions such as friction models, topographic effect, dilatancy and pore pressure. From a modelling point of view, it was shown that upscaling from micro-scale to depth-integrated models is now possible for these fluid-particle flows. All the tools (numerical, experimental, field measurement) are available for a conscientious confrontation on avalanche flows. This should reinforce collaborations between the different communities involved on the topic.

- **Sediment transport**

Sediment transport modelling remains difficult, as the range of scale encountered covers several orders of magnitude. The upscaling from the dynamics of the single grain to sheet flow is, for instance, not obvious. Numerical modelling developed in recent years allows access to these different scales.
Together with theoretical models and experiments, the aim is to be able to model the motion of sediment from the onset up to intense transport. The methods that have been presented during this session were dedicated to the description of this configuration at local scale. The key contributions addressed the modelling of the turbulent flow over the rough bed, the development of dedicated experimental techniques to track each individual grain in the coupled fluid-grain system, and DEM simulations from the onset to intense transport with links to the local rheology of the granular material. Different approaches have been proposed to tackle these key questions, and new collaborations are expected to emerge from Colloquium 588.

- **Morphodynamics**

There is still a great interest in the community in understanding how the motion at the grain scale affects macroscopic quantities such as the morphological characteristics of rivers and/or the development of instabilities at the surface of a granular bed, evolving into ripples and dunes. During the colloquium it has been shown how experiments in wind tunnels and water flumes, and numerical simulations (DNS for the fluid coupled with DEM for the particles) can provide deep insights into the physics that drives the evolution of the interface between the fluid and the granular medium. Key questions such as the definition of ripples and dunes observed in experiments and the physical processes at their origin are still unclear. Recent numerical modelling will allow to improved understanding of these processes.

In conclusion, the colloquium was divided into four main topics, involving different scientific communities. It appeared that the interactions between the different topics allow new approaches to several unsolved problems. We hope that these interactions will lead to several new collaborations to address the questions revealed during Colloquium 588. Encouragingly, 27 participants applied for a one year membership and one participant for a five year membership of EUROMECH.