Title: Collective Dynamics of Particles: from Viscous to Turbulent Flows

Date: May 26, 2014 – May 30, 2014

Location: CISM, palazzo del Torso, Piazza Garibaldi 18, 33100 Udine (Italy)

Course description:

Rationale - The course delivers a comprehensive overview of particulate flows, from low Reynolds numbers to full turbulent flows, and hence will be particularly attractive to graduate students, PhD candidates, young researchers and faculty members in applied physics and chemical-mechanical engineering. The advanced topics and the presentation of current progress in this very active field will also be of considerable interest to many senior researchers, as well as industrial practitioners having a strong interest in understanding the multi-scale complex behavior of such multiphase flows.

Workshop sessions on Tuesday will be chaired by Cristian Marchioli (University of Udine).

The course is organized under the auspices of ERCOFTAC and with the support of COST, through Action FP1005 “Fiber suspension flow modeling” and ANR CoDSPiT “Collective dynamics of settling particles in turbulence”.

Scope - Particulate flows are present in many natural and industrial processes. Transport of sediment in rivers and estuaries, convection of pollutants in the atmosphere, bioconvection of zooplankton, gravity and turbidity currents near coastal shore, pyroclastic flows from volcanic eruptions are a few examples that can be encountered in natural phenomena. In industry, processes involving flows of particles are numerous: among others, fluidized bed reactors, the treatment of waste materials in clarifiers, food processing, and ink technologies. In all the above-mentioned instances, proper understanding and accurate modeling of such complex flows are crucial aspects from scientific and engineering perspectives, as they directly impact the environment we live in.

The understanding of such flows is a daunting task for several reasons. The most straightforward is the very large number of particles one needs to account for. Another equally significant difficulty arises from the subtle coupling between particle-particle and particle-fluid interactions: particles have an effect on the fluid flow (and sometimes even drive it) by exerting stresses on the fluid around them, and in turn the fluid flow modifies the motion of the suspended particles. This two-way coupling often makes attempts at comprehending such flows highly difficult, other than in very simplified settings.

Particulate flows have been examined in the past in a wide variety of situations. A very large number of studies have focused on highly viscous flows in which inertial forces can be neglected. This low-Reynolds-number limit is a valid approximation in small-scale systems or very slow flows, and is often justified when the size of the particles involved in the process is small. In many practical applications, however, fluid inertia cannot be neglected owing the large system sizes, even when the suspended particles are small. In some cases, it is of fundamental importance such as in pyroclastic flows or in fluidized bed reactors where the flows are highly turbulent in spite of the microscopic size of the particles involved.

Several studies have focused on the Lagrangian properties of particles in turbulence (e.g. Lagrangian acceleration) to gain further insight on the relevant forces acting on isolated particles. Preferential concentration and clustering effect of inertial particles in a turbulent flow have been also examined in many recent works. However, collective effects in turbulent particle laden flows have been not thoroughly examined and there is a compelling need to provide a robust body of knowledge in this active field of research.

The scope of the course is therefore to provide a state-of-the-art and accessible survey of numerical and experimental approaches as well as modeling tools for the analysis of collective dynamics of particles in flows. The general approach will be made specific through the most tractable analytically case of low-Reynolds flows but will go beyond viscous flows and will tackle inertial and turbulent flows. The course will also cover the two basic avenues for addressing particulate flows, one being discrete particle simulations and the second being continuum two-phase modeling. In the later, the influence of particles is captured through constitutive relations often resulting from simulations or experiments. The most common discrete methods for the description of particle-laden flows, both in the Stokes regime and in the inertial and turbulent regimes, will be presented and discussed. Among the topics to be included are finite-size particles, deformable particles, and particles of different shapes, in particular rod-like particles or fibers whose interest lies in part in the availability of methods for slender bodies as well as in their importance in industrial applications, such as the fabrication of fibre-reinforced materials and of pulp and paper.

List of Lecturers:

- **Gilles BOUCHET -** Aix-Marseille University, CNRS (FRANCE)
- **Michael BOURGOIN** - University of Grenoble, CNRS (FRANCE)
- **Jason BUTLER** - University of Florida (USA)
- **Holgert HOMANN -** Observatoire de la Côte d'Azur, Nice (FRANCE)
- **John HINCH** - University of Cambridge (UK)
- **Martin MAXEY** - Brown University (USA)

Course homepage: http://www.cism.it/courses/C1402/

Registration: http://www.cism.it/courses/C1402/admission/