TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	June 15	June 16	June 17	June 18	June 19
9.00 - 9.45	Registration	di Prisco	Balachandar	Balachandar	di Prisco
9.45 - 10.30	Mazzuoli	di Prisco	Balachandar	Balachandar	di Prisco
11.00 - 11.45	Aussillous	Chauchat	Mazzuoli	Mazzuoli	Lacaze
11.45 - 12.30	Aussillous	Chauchat	Chauchat	Chauchat	Balachandar
14.00 - 14.45	Lacaze	Workshop	di Prisco	Lacaze	
14.45 - 15.30	Lacaze	Workshop	Mazzuoli	Chauchat	
16.00 - 16.45	Aussillous	Workshop	Aussillous	Lacaze	
16.45 - 17.30	Aussillous	Workshop	Aussillous	Mazzuoli	
18.00	Welcome Aperitif				

ADMISSION AND ACCOMMODATION

The registration fee is 600.00 Euro + VAT*, where applicable (bank charges are not included). The registration fee includes a complimentary bag, four fixed menu buffet lunches (on Friday upon request), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through the following web site: http://www.cism.it. A message of confirmation will be sent to accepted participants. Applicants requiring assistance with the registration should contact the secretariat at the following email address: cism@cism.it.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email to cism@cism.it) no later than two weeks prior to the start of the course.

Cancellation requests received during the two weeks prior to the start of the course will be charged a 50.00 Euro handling fee. Incorrect payments are also subject to a 50.00 Euro handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered lodging and/or board, if available, in a reasonably priced hotel or student guest house.

Requests should be sent to CISM Secretariat by **April 15, 2020** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on the web site www.cism.it, or can be mailed upon request.

* Italian VAT is 22%.

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Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2020
The Erwin Stein Session

PHYSICS OF GRANULAR SUSPENSIONS: MICRO-MECHANICS OF GEOPHYSICAL FLOWS

Advanced School
coordinated by

Marco Mazzuoli
University of Genova, Italy

Laurent Lacaze
IMFT-CNRS
Toulouse, France

Udine *June 15 - 19* 2020

PHYSICS OF GRANULAR SUSPENSIONS: MICRO-MECHANICS OF GEOPHYSICAL FLOWS

The course is an exploration of the recent theoretical, experimental and numerical advancements in the modelling of non-Brownian granular suspensions. The quest is mainly motivated by the growing scientific and engineering interest in geophysical flows as a consequence of the climate change and the severe impact of hydro-geological catastrophic events on socio-economic activities. Among geophysical phenomena, the course focuses on water-saturated sub-aerial and sub-aqueous debris flows, hyper-concentrated flows, underwater turbidity currents, creeping and fluid-like movements of soil in landslides as well as on the sediment transport in rivers and along lake and ocean shores, both at the bed and in suspension.

Indeed, the presence of a liquid, which saturates the interstices between grains, formidably expands the parameter space of granular flows, the mixture exhibiting behaviours typical of either viscous shear-thinning fluids or dense granular flows depending essentially on the average distance between solid particles (i.e. the particle concentration), the relative velocity of particles and the electro-chemo-mechanical properties of the mixture components.

The scope of the course is the investigation of the purely hydraulic problem, thus the liquid is water while particles are in general coarse and inert (non-colloidal and non-adhesive) and, therefore, only their mechanical properties are considered. Nonetheless, a brief excursus on the rheology of more complex suspensions is also planned for the sake of completeness.

The opening of the course is devoted to highlight the striking differences between (dry) granular flows and granular suspensions. Granular suspensions are first classified on the basis of the relative velocity of particles, namely of the particle Reynolds number, into “viscous” and “inertial”, which determines the nature of dominant fluid-solid interactions. Then, “dilute”, “semi-dilute” and “dense viscous suspensions” are distinguished which differ in the number concentration of particles and, therefore, on the role of inter-particle contacts. The dynamics of the granular suspensions under different boundary/initial conditions as well as different driving forces are investigated and modelled highlighting the most recent advancements in the subject. Continuum and discrete approaches are considered. The continuum approach comprises a single-phase, also referred to as “single effective fluid”, or two-phases which indicates that the “theory of mixture” is adopted. As for the discrete approach, it necessarily requires the use of numerical methods to solve the fluid-particle-coupled continuity and momentum equations. The coupling and the inter-particle contacts can be obtained with a point-particle approach or, for “large particles”, by fully resolving the flow field around the particles. The effects due to the presence of turbulent vortices, to the poly-dispersion of particle size and to the particle shape are also considered. Finally, models are described and applied to the aforementioned geophysical flows.

PRELIMINARY SUGGESTED READINGS

Andreotti, B., Forterre, Y., Pouliquen, O., Granular media, Cambridge University Press, 2013.

Balachandar, S., A scaling analysis for point–particle approaches to turbulent multiphase flows. Int J Multiphas Flow, 35(9), 801-810, 2009.

Balachandar, S., Eaton, J.K., Turbulent dispersed multiphase flow, Annual review of fluid mechanics, 2010.

Berzi, D., di Prisco, C.G., Vescovi D., Constitutive relations for steady, dense granular flows, Physical Review E, 2011.

Bougouin, A., Lacaze, L., Granular collapse in a fluid: Different flow regimes for an initially dense-packing. Physical Review Fluids, 3(6), 064305, 2018.

Charru, F., Bouteloup, J., Bonometti, T., Lacaze, L., Sediment transport and bedforms: a numerical study of two-phase viscous shear flow. Meccanica, 51(12), 3055-3065, 2016.

Chauchat J. and M. Médale, A three-dimensional numerical model for dense granular flows based on the rheology, Journal of Computational Physics, Volume 256, 696-712, 2014.

Guazzelli, E., Morris, J.F., A physical introduction to suspension dynamics, Cambridge University Press, 2011.

Guazzelli, E., Pouliquen, O., Rheology of dense granular suspensions, Journal of Fluid Mechanics, 852, P1, 2018.

Ling, Y., Parmar, M., & Balachandar, S., A scaling analysis of added-mass and history forces and their coupling in dispersed multiphase flows. Int J Multiphas Flow, 57, 102-114, 2013.

Maurin, R., J. Chauchat and P. Frey, Dense granular flow rheology in turbulent bedload transport. Journal of Fluid Mechanics, 804, 490–512, 2016.

Mazzuoli, M., Uhlmann, M., Kidanemariam, A.G., Direct numerical simulations of ripples in an oscillatory flow. Journal of Fluid Mechanics, 863, 572-600 (2019).

Mazzuoli, M., Blondeaux, P., Vittori, G., Uhlmann, M., Simeonov, J., Calantoni, J., Interface-resolved direct numerical simulations of sediment transport in a turbulent oscillatory boundary layer. Journal of Fluid Mechanics, (under revision).

Mewis, J., Wagner, N.J., Colloidal suspension rheology, Cambridge University Press, 2011.

Vescovi, D., Marveggio, P., di Prisco, C.G., Saturated granular flows: constitutive modelling under steady simple shear conditions, Géotechnique, 2019.

INVITED LECTURERS

Pascale Aussillous - Aix Marseille Université, France
6 lectures on: From the dynamics at the particle scale towards the continuum approach; rheology of dilute and semi-dilute viscous suspensions; the suspension as a single effective fluid; beyond the single-fluid view: two-phase approach; volume-imposed versus pressure-imposed rheology and application to bedload sediment transport.

Sivaramakrishnan Balachandar - University of Florida, Gainesville, USA
5 lectures on: Dispersed turbulent multiphase flows: mechanisms, time and length scales of importance and statistical descriptions; simulation approaches: Euler-Lagrange methods with fully-resolved physics; particle laden flows in geophysical applications: cutting edge approaches and what simulations offer; Eulerian two-phase flow simulations for gravity and turbidity currents.

Julien Chauchat - LEGI, Domaine Universitaire, Grenoble, France
5 lectures on: Numerical modeling for two-fluid approach; regularization of μ(I) rheology and Granular rheology in bed-load transport; turbulence-particle interactions in sediment transport problems; sheet flow under non-breaking waves: laboratory experiments and Eulerian two-phase flow model; up-scaling of granular processes in larger scale problems (e.g. scour).

Claudio di Prisco - Polytechnic of Milan, Italy
5 lectures on: Rheology of two-phase granular mixtures; poly-dispersed granular suspensions; transition from quasi-static to dynamic conditions in semi-dilute and dense granular suspensions; static liquefaction in granular materials.

Laurent Lacaze - IMFT-CNRS, Toulouse, France
5 lectures on: DEM method and coarse graining for granular flows; rheology extraction of granular/fluid/mixture phase in dense fluid particle flows; resolved vs meso-scale model applied to sediment transport; ripples and dunes; collapse as a model of debris flow, their implication in applications.

Marco Mazzuoli - University of Genova, Genova, Italy
5 lectures on: Introduction to granular suspensions in geophysical flows; sediment transport in turbulent flow: interaction between particles and vortex structures; DNS of sediment transport under non-breaking waves; DNS of marine sand ripples; transport of fine sediments: hints on the rheology of colloidal suspensions.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.