

## TIME TABLE

(Registration on Monday at 8.30)

TIME	Monday September 14	Tuesday September 15	Wednesday September 16	Thursday September 17	Friday September 18
9.00 - 9.45	Minier	Marchioli	Lundell	Henry	Minier
9.45 - 10.30	Minier	Marchioli	Lundell	Henry	Minier
11.00 - 11.45	Pozorski	van Hout	Voth	Lundell	Pozorski
11.45 - 12.30	Pozorski	van Hout	Voth	Lundell	Pozorski
14.00 - 14.45	Marchioli	Pozorski	Minier	Voth	
14.45 - 15.30	Marchioli	Pozorski	Minier	Voth	
16.00 - 16.45	van Hout	Henry	Workshop	Workshop	
16.45 - 17.30	van Hout	Henry	Workshop	Workshop	

## ADMISSION AND ACCOMMODATION

The registration fee is of 490,00 Euro + VAT taxes\*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday subject to numbers), 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 our web site: <http://www.cism.it> or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

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

If cancellation occurs less than two weeks prior to the start of the course, a Euro 50,00 handling fee will be charged. Incorrect payments are subject to Euro 50,00 handling fee.

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

Requests should be sent to CISM Secretariat by **July 14, 2015** 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 our web site, or can be mailed upon request.

Please note that the Centre will be closed for summer vacation the first three weeks in August.

\* Italian VAT is 22%.

*For further information please contact:*

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Palazzo del Torso  
Piazza Garibaldi 18  
33100 Udine (Italy)  
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# PARTICLES IN WALL-BOUNDED TURBULENT FLOWS: DEPOSITION, RE-SUSPENSION AND AGGLOMERATION

Advanced School  
coordinated by

**Jean-Pierre Minier**  
Electricité de France R&D  
Chatou, France

**Jacek Pozorski**  
IMP, Polish Academy of Sciences  
Gdansk, Poland

Sponsored by



Udine September 14 - 18 2015

# PARTICLES IN WALL-BOUNDED TURBULENT FLOWS: DEPOSITION, RE-SUSPENSION AND AGGLOMERATION

Particle transport in near-wall turbulent flows involves challenging phenomena, such as deposition, re-suspension and agglomeration, which cover a wide range of situations from single-particle deposition to the formation of deposited aggregates that modify fluid flows. These issues have implications in many processes ranging from power-generation industries to electronics, food industry, water treatment, micro-mechanics and micro-biology and are also found in environmental or medical contexts.

What is referred to as 'particle deposition' is best addressed by introducing a coupling between the underlying phenomena (deposition, re-suspension, agglomeration, clogging) which reveals that three fundamental physical interactions are at play: particle/fluid, particle/surface and particle/particle interactions.

There are thus two major mechanisms: the hydrodynamic transport, describing particle/fluid interactions and how particles are transported and dispersed by turbulent flows, and the attachment mechanism, describing particle/surface and particle/particle interactions and how particles adhere to surfaces. The related phenomenology has often been addressed from two separate points of view using: either a hydrodynamic approach but with a poor description of attachment forces or a physico-chemical standpoint but with no proper account for particle transport. However, new descriptions have emerged with the development of multi-scale models. Furthermore, new insights have been provided by Direct Numerical Simulation (DNS) and by fine experimental techniques (such as PIV/PTV or AFM), leading to an improved

understanding of particle deposition. With respect to this context, the course has a three-fold objective:

- To provide an in-depth presentation of the phenomenology involved in particle dynamics in wall-bounded turbulent flows and of the basic physical interactions;
- To introduce unified models of particle deposition (which combine hydrodynamic and physico-chemical approaches) that are helpful to achieve a comprehensive description of the complete phenomenon;
- To discuss open experimental/modelling issues, for example multi-layer deposition and re-suspension.

The general terminology of 'particles' does not mean that the course will be strictly limited to solid (colloidal or inertial)

spherical particles. Indeed, specific lectures will also discuss droplets (coalescence/breakup) and non-spherical particles, such as fibre suspensions in turbulent flows. The course is organised so as to cover the different aspects of the physics involved in particle behaviour in turbulent flows (thus, the transport/attachment mechanisms) and the variety of points of view (experimental/numerical/modelling). The present course will be attractive to graduate and doctoral students, to young researchers as well as to practicing engineers in the fields of mechanical, nuclear, environmental, medical, chemical and process engineering. Since the course includes presentations of up-to-date progress as well as open questions that remain to be addressed, it will be also of interest for senior researchers.

## PRELIMINARY SUGGESTED READINGS

Minier, J.-P. and Peirano, E. "The PDF approach to turbulent polydispersed two-phase flows", *Physics Reports*, 352 (2001), 1-214.

Henry, C., Minier, J.-P. and Lefèvre, G. "Towards a description of particulate fouling: from single particle deposition to clogging", *Advances in Colloid and Interface Science*, 185-186 (2012), 34-76.

Israelachvili, J. N. "Intermolecular and Surface Forces", Academic Press, Third Edition, 2011.

Pope, S. B., "Turbulent Flows", Cambridge University Press, 2000.

Soldati, A. and Marchioli, C. "Physics and modeling of turbulent particle deposition and entrainment: review of a systematic study", *International Journal of Multiphase Flow*, 35 (2009), 827-839.

## INVITED LECTURERS

**Jean-Pierre Minier** - EDF R&D, MFEE, Chatou, France  
*6 lectures on:* General introduction on the phenomenology of particle deposition and on the modelling issues involved. Introduction to Lagrangian stochastic approaches and multi-scale models that include both transport and physico-chemical effects. Applications to single- and multi-layer deposition simulations.

**Jacek Pozorski** - IMP, Polish Academy of Sciences, Gdansk, Poland  
*6 lectures on:* Presentation of fluid turbulence with an emphasis on near-wall regions: statistical modelling approaches as well as alternative formulations, such as LES (Large Eddy Simulation). Current models for particle dynamics and transport in near-wall turbulence. Numerical prediction of agglomeration.

**Christophe Henry** - IMP, Polish Academy of Sciences, Gdansk, Poland  
*4 lectures on:* Presentation of inter-surface forces, in particular the DLVO theory. Recent perspectives showing the importance of surface heterogeneities (surface roughness or electrostatic heterogeneities) and new approaches for particle re-suspension.

**Fredrik Lundell** - Linné FLOW Centre & Wallenberg Wood Science Centre, KTH, Royal Institute of Technology, Stockholm, Sweden  
*4 lectures on:* Introduction to the physics of fibre suspensions in turbulent flows. Discussion of the general phenomenology and the links with practical applications. Presentation of rheological approaches with special attention to flocculation.

**Cristian Marchioli** - University of Udine, Italy  
*4 lectures on:* Introduction to the forces acting on particles in turbulent flows and the physics of particle-laden flows. Discussion and analysis of DNS-based results for both spherical and non-spherical particles, with an emphasis on the role played by near-wall fluid structures.

**René van Hout** - Technion-Israel Institute of Technology, Haifa, Israel  
*4 lectures on:* Presentation of experimental aspects (such as particle image velocimetry and holography techniques) and of how experimental results are currently helping progress in the understanding of particle motion and near-wall dynamics.

**Greg Voth** - Wesleyan University, Middletown, CN, USA  
*4 lectures on:* Presentation of experimental aspects. Discussion of results from direct simulations and analysis of special issues such as non-spherical particle alignment in fluid flows and fluid stretching for the description of particle agglomeration and breakup.

## 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.

**PARTICLES IN WALL-BOUNDED TURBULENT FLOWS:  
DEPOSITION, RE-SUSPENSION AND AGGLOMERATION**

**Udine, September 14 - 18, 2015**

**Application Form**

(Please print or type)

Surname \_\_\_\_\_

Name \_\_\_\_\_

Affiliation \_\_\_\_\_

Address \_\_\_\_\_  
\_\_\_\_\_

E-mail \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_

**Method of payment upon receipt of confirmation (Please check the box)**

*The fee is 490,00 Euro + 22% Italian VAT taxes, where applicable (bank charges are not included).*

I shall send a check of Euro \_\_\_\_\_

Payment will be made to CISM - Bank Account No. 094570210900,  
VENETO BANCA - Udine (CAB 12300 - ABI 05035 - SWIFT/BIC  
VEBHIT2M - IBAN CODE IT46 N 05035 12300 09457 0210900).  
Copy of the receipt should be sent to the secretariat

I shall pay at the registration counter with check or VISA Credit Card  
(Mastercard/Eurocard, Visa, CartaSi)

**IMPORTANT: CISM is obliged to present an invoice for the above sum.  
Please indicate to whom the invoice should be addressed.**

Name \_\_\_\_\_

Address \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

C.F.\* \_\_\_\_\_

VAT/IVA\* No \_\_\_\_\_

(\* Only for EU residents or foreigners with a permanent business activity in Italy.)

**Only for Italian Public Companies**

I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).

**Privacy policy:** I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.

Complete information on CISM's privacy policy is available at [www.cism.it](http://www.cism.it).

I have read the "Admission and Accommodation" terms and conditions and agree.

Date \_\_\_\_\_ Signature \_\_\_\_\_