

## TIME TABLE

TIME	Monday June 17	Tuesday June 18	Wednesday June 19	Thursday June 20	Friday June 21
9.00 - 9.45	Registration	Sommerfeld	Lundell	van Wachem	Climent
9.45 - 10.30	Marchioli	Sommerfeld	Marchioli	van Wachem	van Wachem
11.00 - 11.45	Toschi	Lundell	Shaqfeh	Climent	van Wachem
11.45 - 12.30	Toschi	Lundell	Shaqfeh	Climent	van Wachem
14.00 - 14.45	Lundell	Shaqfeh	Marchioli	Workshop	
14.45 - 15.30	Lundell	Shaqfeh	Marchioli	Workshop	
16.00 - 16.45	Sommerfeld	Toschi	Climent	Workshop	
16.45 - 17.30	Sommerfeld	Toschi	Climent	Workshop	

## ADMISSION AND ACCOMMODATION

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.

The 700,00 Euro registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday not included), hot beverages, on-line/downloadable lecture notes and wi-fi internet access.

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. Requests should be sent to CISM Secretariat by **April 17, 2013** 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.

*For further information please contact:*

CISM  
 Palazzo del Torso  
 Piazza Garibaldi 18  
 33100 Udine (Italy)  
 tel. +39 0432 248511 (6 lines)  
 fax +39 0432 248550  
 e-mail: [cism@cism.it](mailto:cism@cism.it)



Centre International des Sciences Mécaniques  
 International Centre for Mechanical Sciences

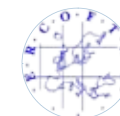
ACADEMIC YEAR 2013  
 The van Dyke Session

## NON-SPHERICAL PARTICLES AND AGGREGATES IN FLUID FLOWS

COST/ERCOTAC Training School  
 coordinated by

**Cristian Marchioli**  
 Università di Udine  
 Italy

**Federico Toschi**  
 Eindhoven University of Technology  
 The Netherlands



European Research Community  
 On Flow, Turbulence And Combustion

**Udine, June 17 - 21, 2013**

# NON-SPHERICAL PARTICLES AND AGGREGATES IN FLUID FLOWS

Dynamics of non-spherical particles and aggregates in fluid flow are encountered both in nature and in industrial applications. Examples for non-spherical particles include airborne solid particles or aerosols, carbon nanotubes, micro-organisms like phytoplankton, sediment-laden flows and wood-fibre suspensions. Particle aggregates are found in chemical, industrial or material processes for colloids and in polymer manufacturing. In these processes, particle size ranges from several nanometers to several centimeters, with loadings that may substantially change the macroscopic (rheological) properties of the suspension flow. On the other hand, transport and interaction of particles/aggregates in complex (e.g. turbulent) flows is governed by a number of physical processes occurring at a wide range of different scales. The rapidly increasing computational power has recently made feasible three-dimensional, time-dependent simulations of non-ideal particles in fluid flows, producing an entire branch of flourishing literature which is fostering research in dispersed multiphase flow. Progress has been substantial also

from an experimental viewpoint, with improved measurement techniques based on optics or magnetic resonance flow imaging. Due to the multiscale nature of the problem, investigation and modelling require synergetic use of such approaches. Objective of the course is to provide a general and unified frame of the current research on the dynamical behaviour of non-spherical particles and particle aggregates in complex flows and put future research paths in perspective. The focus will be on generic aspects and physics of non-ideal particle suspensions (e.g. rheological properties in suspensions of anisotropic deformable particles, and modulation of turbulence induced by particles/aggregates). Issues related to modelling and physical understanding at all various length scales will be covered: from the scale resolving the complex flow around individual non-spherical particles, to large eddy simulation models for flows with particles, to large-scale Eulerian-Eulerian models. Among the topics to be included are particle dynamics in free and wall-bounded turbulence,

fluid-particle interactions, collision modelling, break-up and agglomeration, advances in measurement and simulation techniques, and rheological modelling. The lectures will also provide a wide overview of cutting-edge work in this very active area of multiphase flow research and focus in more detail on a few advanced topics of significant practical and theoretical value in several areas of engineering and applied physics. This will reinforce understanding of the fundamental phenomena and their importance, providing participants with varied conceptual and methodological tools applicable to problems at hand. After the lectures, students should possess the necessary knowledge of the basic capabilities, potentials and limitations of the various numerical and experimental methods taught and, hence, should be able to critically evaluate the reliability and accuracy of the information these methods can provide when applied to practical situations.

The course delivers a comprehensive overview of non-ideal particle/aggregate dynamics in complex fluids, 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 research interest in understanding the multi-scale complex behavior of such multiphase flows, with particular emphasis on turbulent flows.

*The course will be organized under the auspices of ERCOFTAC's SIG12 "Dispersed Turbulent Two-Phase Flows" and SIG43 "Fiber suspension flow modelling" and with the support of two COST Actions: Action FP1005 "Fiber suspension flow modelling: a key for innovation and competitiveness in pulp & paper industry" and Action MP0806 "Particles in Turbulence".*

## PRELIMINARY SUGGESTED READINGS

A. Prosperetti, G. Tryggvason (Eds.) Computational methods for multiphase flows, Cambridge (2009).

S.G. Advani, C.L. Tucker III, "The use of tensors to describe and predict fiber orientation in short fiber composites," *IchJ. Rheol.* 31 (1987), 751-784.

M. Dietzel, M. Ernst, M. Sommerfeld, "Application of the lattice-boltzmann-method in two-phase flow studies: from point-particles to fully resolved particles", *Proceedings of ASME-JSME-KSME Joint Fluids Engineering Conference 2011*, July 24-29, 2011, Hamamatsu, Shizuoka, JAPAN.

M. Sommerfeld, "Modelling particle collisions and agglomeration in gas-particle flows", 7<sup>th</sup> International Conference on Multiphase Flow, May 30-June 4, 2010, Tampa, USA.

R. Powell, "Experimental techniques for multiphase flows", *Phys. Fluids*, 20 (2008), 040605.

E. Climent, M. Maxey, "The force coupling method: A flexible approach for the simulation of particulate flows," *In Theoretical Methods for Micro Scale Viscous Flows* (2009), François Feuillebois and Antoine Sellier (Eds.).

## INVITED LECTURERS

**Cristian Marchioli** - Università di Udine, Italy  
*4 Lectures on:* General introduction to the scope of the course. Fundamentals and key definitions for modelling in physics and engineering. Euler-Lagrange methods for Direct and Large-Eddy simulation of non-spherical particles. Applications to turbulent dispersion of elongated fibers in shear flow.

**Federico Toschi** - Eindhoven University of Technology, The Netherlands  
*4 Lectures on:* Euler-Lagrange methods for DNS/LES of non-spherical particles and aggregates in homogeneous isotropic turbulence: fundamentals and applications. Lattice Boltzmann Methods (LBM): fundamentals and applications. Numerical prediction of break-up, deformation and agglomeration/coalescence in turbulent flow.

**Fredrik Lundell** - Royal Institute of Technology, Stockholm Sweden  
*5 Lectures on:* Experimental methods for non-spherical particles and aggregates in laminar/turbulent flows. Application to measurement of fiber suspension flows.

**Eric Shaqfeh** - Stanford University, CA, USA  
*4 Lectures on:* Transport mechanics of complex fluids, dynamics and rheology of suspensions of anisotropic and deformable particles, from molecular simulations to large-scale simulations. Rheological modelling: fundamentals and applications.

**Eric Climent** - Institut de Mécanique des Fluides, Toulouse, France  
*5 Lectures on:* Numerical modelling of finite-size particles/bubbles and non-colloidal suspensions in shear flows. Force coupling methods for fully-resolved particle-level simulations. Modulation of homogeneous turbulence seeded with finite size particles or bubbles.

**Berend Van Wachem** - Imperial College, London, UK  
*5 Lectures on:* Euler-Euler methods for particles in flows. Drag, lift and torque coefficients for non-spherical particles in fluid flow. Numerical approaches: Large-Eddy simulation techniques, Immersed Boundary Method (IBM). Fundamentals and applications.

**Martin Sommerfeld** - Martin Luther University, Wittenberg, Germany  
*4 Lectures on:* Numerical simulation of agglomeration and aggregate dynamics: modelling of particle collision and agglomeration in turbulent flows, characterization of the morphology of aggregated particles. Analysis of aggregates behavior in laminar and turbulent flow using LBM.

## LECTURES

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

**NON-SPHERICAL PARTICLES AND AGGREGATES  
IN FLUID FLOWS**

**Udine, June 17 - 21, 2013**

**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 of Euro 700,00 includes IVA/VAT tax and excludes bank charges*

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

*Payment will be made to CISM - Bank Account N° 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, cash 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 \_\_\_\_\_