TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 28	**May 29**	**May 30**	**May 31**	**June 1**
9.00 - 9.45	Registration	Hills	Hills	Barber	Almqvist
9.45 - 10.30	Hills	Hills	Hills	Barber	Almqvist
11.00 - 11.45	Hills	Barber	Barber	Paggi	Paggi
11.45 - 12.30	Paggi	Barber	Barber	Paggi	Paggi
14.00 - 14.45	Barber	Paggi	Almqvist	Dini	
14.45 - 15.30	Almqvist	Paggi	Almqvist	Dini	
16.00 - 16.45	Dini	Dini	Hills	Almqvist	
16.45 - 17.30	Dini	Dini	Dini	Almqvist	
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 **March 28, 2018** 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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ACADEMIC YEAR 2018
The Cowin Session
Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

MODELLING AND SIMULATION OF TRIBOLOGICAL PROBLEMS IN TECHNOLOGY

Advanced School
coordinated by

Marco Paggi
IMT School for Advanced Studies Lucca
Italy

David Hills
University of Oxford
UK

Udine ***May 28 - June 1*** **2018**

MODELLING AND SIMULATION OF TRIBOLOGICAL PROBLEMS IN TECHNOLOGY

Significant advances in contact mechanics have been achieved since the first theoretical derivations a few centuries ago, primarily associated with contact problems in statics and dynamics involving friction, adhesion, wear, roughness, heat or electric conduction, and also with materials not only linear elastic. Principles of contacts mechanics can be applied in many traditional mechanical engineering areas such as locomotive wheel-rail contact, coupling devices, braking systems, tires, bearings, combustion engines, mechanical linkages, gasket seals, metal forming, ultrasonic welding, electrical contacts, and many others. Current challenges in the field regard the extension of contact mechanics methodologies to the micro- and the nano-scales, to coupled multi-field problems, and the application to finite elasticity.
The main objective of this course is to convey, in a self-contained manner, the fundamental concepts for the classification of the types of contact, the mathematical methods for the formulation of the contact problems, and the numerical procedures required for their solution. In addition to the methodologies, a wide class of applications will be covered, including contact problems in mechanical engineering, microelectronics and nanomechanics.
A taxonomy of contacts and the half-space solutions for linear elastic problems will be provided. For the class of complete contacts, asymptotic methods are formulated and applied to mechanical engineering problems. Further concepts for modelling contact problems with friction and partial slip will also be provided. Methods to formulate contact problems in the presence of coupled fields, such as thermo-elastic and electro-elastic contact problems, are then presented together with applications to mechanical engineering and microelectronics. An overview on numerical methods for the approximate solution of contact problems will also be provided (boundary element method, finite element method, molecular dynamics) with attention to complex problems characterized by multi-scale roughness, emphasizing the advantages and disadvantages of each technique. Finally, advanced contact problems involving lubrication, roughness and interaction between bodies undergoing finite deformation will complete the course.
Each set of lectures will be designed to convey a strong background on theory and numerical methods, with also in-depth treatment of cutting-edge research topics and applications.

The final aim of this intensive course is to provide a compact yet comprehensive overview of contact mechanics in technology and its current challenges.

The lectures are primarily tailored for doctoral students of applied mathematics, mechanics, engineering and physics with a strong research interest in theoretical modeling, numerical simulation and experimental characterization of contact problems in technology. They are also suited for young and senior researchers in the above-mentioned and neighboring fields working in academia or in private research and development centers, interested in gaining a compact yet comprehensive overview of contact mechanics from its fundamental mathematical background, to the computational methods and the experimental techniques available for the solution of contact problems.

PRELIMINARY SUGGESTED READINGS

Johnson KL (1985) Contact Mechanics, Cambridge University Press, ISBN 0521347963.

Ahn YJ, Bertocchi E, Barber JR (2008) Shakedown of coupled two-dimensional discrete frictional systems. Journal of the Mechanics and Physics of Solids, 56:3433-3440, doi:10.1016/j.jmps.2008.09.003.

Almqvist A, Fabricius J, Larsson R, Wall P (2014) A new approach for studying cavitation in lubrication. Journal of Tribology, 136:011706, doi:10.1115/1.4025875.

Barber JR (2016) Nominally static frictional contacts under periodic loading. The Journal of Strain Analysis for Engineering Design, 51:270-278, doi:10.1177/0309324715602844.

Bemporad A, Paggi M (2015) Optimization algorithms for the solution of the frictionless normal contact between rough surfaces. International Journal of Solids and Structures, 69-70:94-105, doi:10.1016/j.ijsolstr.2015.06.005.

Churchman CM, Hills DA (2006) General results for complete contacts subject to oscillatory shear. Journal of the Mechanics and Physics of Solids, 54:1186-1205, doi: 10.1016/j.jmps.2005.12.005.

Dini D, Sackfield A, Hills DA (2005) Comprehensive bounded asymptotic solutions for incomplete contacts in partial slip. Journal of the Mechanics and Physics of Solids, 53:437-454, doi: 10.1016/j.jmps.2004.06.011.

Paggi M, Pohrt R, Popov VL (2014) Partial-slip frictional response of rough surfaces. Scientific Reports, 4:05178, doi:10.1038/srep05178.

Paggi M, Barber JR (2011) Contact conductance of rough surfaces composed of modified RMD patches. International Journal of Heat and Mass Transfer, 54:4664-4672, doi:10.1016/j.ijheatmasstransfer.2011.06.011.

Profito FJ, Vldescu S-C, Reddyhoff T, Dini D (2017) Transient experimental and modelling studies of laser-textured micro-grooved surfaces with a focus on piston-ring cylinder liner contacts. Tribology International, 113:125-136, doi:10.1016/j.triboint.2016.12.003.

INVITED LECTURERS

Andreas Almqvist - Luleå University of Technology, Sweden
7 lectures on: thin film flow modelling including hands-on finite difference method implementation of a solution procedure for the 2D Reynolds equation in cylindrical coordinates, analytical solutions, scaling to non-dimensional form, modelling cavitation in hydrodynamic lubrication by means of the linear complementarity problem and numerical solution procedures.

James R. Barber - University of Michigan, Ann Arbor, USA
7 lectures on: the effect of friction in contact problems, the Amonton's law of friction, existence and uniqueness of solutions, Klarbring's P-matrix criterion, memory effects, wedging, Iwan models, energy dissipation during periodic loading, shakedown theorems, effect of coupling in half-space problems, Dundurs bimaterial parameters, inverse problems, slip waves, instability and frictional vibrations, rate-state models.

Daniele Dini - Imperial College London, UK
7 lectures on: contact mechanics of dry contacts in the presence of roughness and adhesion and links to friction and vibrations, visco-elastic contact problems, lubricated contacts with particular application to textured surfaces and bearings, molecular dynamics simulations and multi-scale formulations.

David A. Hills - University of Oxford, UK
7 lectures on: taxonomy of contacts, half-plane formulations, complete contact problems, asymptotic techniques, partial slip problems for all contact classes, with particular attention to half-plane problems with complex loading cycles (varying tension, shear and normal load).

Marco Paggi - IMT School for Advanced Studies Lucca, Italy
7 lectures on: physico-mathematical modelling of the constitutive response of interfaces; computational methods for the solution of normal and tangential contact problems with roughness, with special attention to the boundary element method and the finite element method; mathematical analogies to predict thermal and electric contact resistances at a rough interface; contact problems with elasto-plasticity, adhesion, finite elasticity, advanced multi-field coupled problems.

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.