UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Multiscale and multiphysical modelling of materials: chemo-mechanics of smart hydrogels and biological tissues"

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Short Abstract: Constitutive modelling in Mechanics is the art of describing the mechanical properties of materials by means of mathematical problems, which are formulated in connection with physical concepts and experimental evidence. The analysis and design of novel products can take advantage from numerical simulations only if constitutive models provide a comprehensive description of materials behavior. For advanced applications, material responses have to be analyzed from a multiscale and multiphysical perspective. This is true for instance when addressing material design for smart behaviors (e.g., hydrogels) or in the analysis of biological tissues and bioprosthetic products. Therefore, constitutive models should correlate macroscale mechanical properties with the behavior and the arrangement of constituents. Moreover, physico-chemical processes taking place at small scales have to be modelled since triggering an effective behavior at larger scales.

This course opens with the general mathematical requirements of constitutive laws for the mechanical behaviour of materials in a finite strain framework. Then, the micromechanical approach for material homogenization is described, introducing the rationale behind multiscale approaches. Furthermore, thermodynamic requirements of multiphysical constitutive laws are outlined and applied in the context of chemomechanical systems. Specific applications on smart hydrogels and biological tissues will be presented, describing and connecting multiphysical descriptions and multiscale effects.

Course Contents in brief:

- Constitutive laws for the mechanical behaviour of materials in a finite strain framework
- Micromechanical approach for material homogenization
- Thermodynamic requirements of multiphysical constitutive laws
- Applications on smart hydrogels and biological tissues

Total # of hours of lecture: 20

References:

[1] M. Marino, G. Pontrelli, G. Vairo, P. Wriggers. A chemo-mechano-biological formulation for the effects of biochemical alterations on arterial mechanics: the role of molecular transport and multiscale tissue remodeling. J. R. Soc. Interface 14, pp. 20170615(17), 2017.

[2] M. Marino, P. Wriggers. Micro-macro constitutive modeling and finite element analytical-based formulations for fibrous materials: A multiscale structural approach for crimped fibers, Comput. Methods Appl. Mech. Engrg., vol. 344, pp. 938-969, 2019.

[3] A. Hajikhani, F. Scocozza, M. Conti, M. Marino, F. Auricchio, P. Wriggers. Experimental characterization and computational modeling of hydrogel cross-linking for bioprinting applications. Int. J. Art. Organs, vol. 42, pp. 548-557, 2019.

CV of the Teacher

Michele Marino (http://dicii.uniroma2.it/MARINO) received his Bachelor and Master Degree in Medical Engineering, respectively in 2005 and 2008, at the University of Rome Tor Vergata. In 2007/2008, he has been also visiting scholar researcher at the University of Leeds thanks to a Leonardo da Vinci scholarship from the European Commission. In 2013, he has achieved a PhD in Structural Mechanics at the University of Rome Tor Vergata and, in 2015, he has received with an Alexander von Humboldt Fellowship for a two-year research period in Germany (selection process based on peer-review with less than 30% success). He has been hosted at the Institute of Continuum Mechanics (IKM) of the Leibniz University of Hannover, one of the leading Institute for Computational Mechanics in the world, directed by Professor Peter Wriggers. From 2017 to 2019, he has been Group Leader for Predictive Simulation in Biomechanics at IKM, where he supervises two PhD students, and he has been lecturer of three courses on linear and nonlinear finite elements and mechanics of advanced materials for Bachelor and Master Degrees in Civil, Medical and Mechanical Engineering. Since 2020, he received a tenure-track young professorship within the Rita-Levi Montalcini Program granted by the Ministry of Education, University and Research in Italy (selection process based on peer-review with less than 8% success). Accordingly, he is currently Assistant Professor in Mechanics of Materials and Structures at DICII in UNITOV, where he is lecturer of two courses on structural and computational mechanics.

Michele Marino has co-authored 25 papers on peer-reviewed International Journals and 6 chapters in International Books, including a chapter on Constitutive Modelling in the Encyclopedia of Biomedical Engineering. His expertise cover: multiscale constitutive modelling, multiscale finite element analyses, parameters identification and optimization problems, chemo-mechano-biological modelling, and damage mechanics. In 2019, he received the Prize AIMETA Junior on Mechanics of Solids and Structures, given by the Italian Association of Theoretical and Applied Mechanics, awarded every two-year to two young researchers below 40 years old. As institutional responsibilities, he is President of the Italian Chapter of the European Society of Biomechanics since 2015, and member of the board of the Biomechanics Group of the Italian Association of Theoretical and Applied Mechanics since 2018.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

Day1 – 4 hours

Constitutive laws for the mechanical behaviour of materials in a finite strain framework

Day2 – 4 hours

Micromechanical approach for material homogenization

Day3 – 4 hours

Thermodynamic requirements of multiphysical constitutive laws

Day4 – 4 hours

Applications on smart hydrogels

Day5 – 4 hours

Applications on biological tissues