InterPore Foundation

KIMBERLY-CLARK DISTINGUISHED LECTURESHIP AWARD 2022

Lecturer: Prof. Jacques M. Huyghe
University of Limerick
Eindhoven University of Technology

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Prof. Jacques Huyghe
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LECTURE OPTION A:
POROMECHANICS IN EXTREMELY LARGE DEFORMATION: SWELLING AND FRACTURE

Biomedical engineers face porous media with very low stiffness, high osmolarity and extremely large deformations. Examples are superabsorbent hydrogels and living cells. Volume strains above 1000 % strain are commonplace in diapers, female pads and growth plates. The strong nonlinearities of large deformation formulations of poromechanics hamper the use of analytical solutions. Large deformation u-p formulations fail in this regime. This means that simulation tools of poromechanics are inapt to a great deal of biology, which typically unfolds in the intracellular space. Local mass balance violation is the culprit under extremely large deformations. In order to address this issue, we developed a mixed hybrid formulation of poromechanics of swelling gel based on a Raviart-Thomas finite element. This formulation strictly complies with local mass balance. Swelling computations are possible down to a shear modulus of 10 kPa. Surface instabilities easily develop as osmotic forces overtake the stabilising effect of the elasticity. Fracture simulation using large deformation XFEM including flow within the crack, between the crack and the formation and within the crack, allows for initiation, coalescence and bifurcation of cracks. XFEM computations predict experimentally observed staccato propagation of cracks in hydrogels. Constitutive modelling of swelling require the concurrent use of elastic, mixing and ionic energies in Flory-Rehner swelling model. Interaction terms between elastic and ionic energies occur because the stiffness of gels directly depends on ionic concentrations. Future perspectives on constitutive modelling of swelling and fracturing gels include herniation of intervertebral disc, mechanotransduction of extracellular matrix and design of biomimetic hydrogels. Hydraulic fracturing of shale is an important geotechnical application.

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LECTURE OPTION B:
THE HEART: THE ONLY PUMP THE FAILURE OF WHICH CANNOT BE ASSESSED THROUGH STRESS ANALYSIS

Technological advances in computational mechanics allow to simulate failure of any part of airplanes, pumps, compressors, electric power stations, foundations, bridges, etc. Billions of dollars have been invested to calculate 3D stress configuration in engineering structures. Why stress? Because the criterion of failure in engineering structures is generally excess stress. Failure of the human heart is responsible for 6 million deaths per year worldwide. Models of cardiac mechanics have been developed to analyse cardiac pump function from tissue to organ scale. All of these models focus on stress and strain. However, heart failure is not associated with fracture. Failure of a heart is usually induced by a mismatch between blood perfusion and metabolic needs of the cardiomyocytes. Blood perfusion is defined as the capillary blood flow per unit volume of tissue. Its dimension is ml s-1ml-1=s-1. Typical values at rest are 0.02 s-1. Blood flows into the myocardium through a complex tree of arterial vessels, reaching a dense network of more than 3000 capillaries per mm2. A tree of venous vessels mostly parallel to the arterial tree drains the blood. Because failure is associated with blood perfusion and present day models do not address this failure mechanism, there is an urgent need for a computational strategy for blood perfusion in deforming myocardial tissue. Upscaling of the vessel trees opens the way to computation of coronary blood flow in a multi compartment poro-mechanical model of the beating heart. Arterial, arteriolar, capillary, venular and venous blood are treated as separate compartments. As a result, the supply of oxygen to the tissue is modelled. Combining this with a local metabolism and autoregulation, a precise criterion of failure is implemented to predict cardiac pathologies and the impact of interventions on heart function. Through the design of a virtual environment for testing cardiac interventions, the time to market of all newly designed devices and therapies will be shortened substantially.

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BIO OF PROF. JACQUES HUYGHE

Jacques Huyghe holds a Master degree in Civil Engineering from Ghent University, Belgium (1979) and a Ph.D. from Eindhoven University of Technology, The Netherlands. Jacques Huyghe has a unique signature in that he has been working at the interface between biomedical and petroleum engineering. He advertised repeatedly the close analogies between biological tissues and geomaterials and the urgent need to exploit these analogies in developing numerical models and industrial/clinical technologies. He authors more than 125 full-size SCI-publications, is the recipient of many awards among which a Royal Dutch Shell donation (1995-1998), a fellowship of the Royal Netherlands Academy of Arts and Sciences (1996-2001) and a swelling materials Interpore Award (2013). He has been cooperating with many industrial partners among which Philips Research, Shell Research and Procter and Gamble. His present interest is in mechanotransduction through voltage gated ion channels in intervertebral disc, swelling and fracture of superabsorbents and poromechanical modelling of coronary blood flow and microvascular flow of red blood cells.

INTERPORE FOUNDATION

InterPore Foundation for Porous Media Science and Technology is a non-profit, non-governmental, independent organization. It was founded by the International Society for Porous Media in 2016.

Find out more about the foundation at:
https://www.interpore.org/interpore-foundation/

KIMBERLY-CLARK DISTINGUISHED LECTURESHIP AWARD

Among other awards, each year, InterPore will select a porous media researcher with a very high international recognition as the "InterPore Kimberly-Clark Distinguished Lecturer on Porous Media Science & Technology". The awardee will share a topic relevant to the industrial porous media community through a series of lectures at various member and non-member organizations.

A word of gratitude:

This award has been made possible by a generous grant from Kimberly-Clark, home to some of the world's most iconic and trusted brands, including: Huggies, Scott, Kleenex, Cottonelle and Kotex. For more than a century Kimberly-Clark has been transforming insights and technologies into innovative products and services that improve the lives of nearly a quarter of the world's population.

HOW TO APPLY

Are you interested in hosting Jacques Huyghe at your institution? Please submit your application online. Non-members may also apply.

To request the presentation, please visit: https://www.interpore.org/awards/kimberly-clark-distinguished-lectureship/
download and fill out the application form and return it by e-mail.

For further questions please contact: *executive-officer@interpore.org*

Please be aware that the lecturer availability will be limited and not all requests can be honored by the lecturer.

LECTURE OPTIONS

Due to the COVID-19 pandemic's continual effect on international travel, Prof. Huyghe will also be offering the option of online and hybrid lectures (some audience members attend in person and others virtually) in addition to in-person appearances.

Hosts may select from one of the two lectures detailed in this brochure.

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