City University of Hong Kong

Hong Kong Society of Theoretical and Applied Mechanics

Shanghai Society of Theoretical and Applied Mechanics

Proceedings of

The 24th Annual Conference of HKSTAM 2020

The 16th Shanghai – Hong Kong Forum on Mechanics and Its Application

December 5, 2020

Hong Kong

Editors

Heung-fai LAM and Xinrui NIU

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PREFACE

The 24th Annual Conference of HKSTAM 2020 in conjunction with the 16th Shanghai–Hong Kong Forum on Mechanics and Its Application was held during December 5, 2020 in City University of Hong Kong. Due to the COVID-19 pandemic, the conference was implemented in an online manner. This conference is co-organized by the Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM), the Shanghai Society of Theoretical and Applied Mechanics (SSTAM), and City University of Hong Kong (CityU). The conference aims to provide a platform for all scientists, engineers, and students in the various fields of mechanics and related areas to share, communicate and exchange ideas, and to enhance co-operations within relevant parties. This proceeding consists of 60 abstracts including 5 Distinguish Lectures by Prof. Ming ZHANG from The Hong Kong Polytechnic University, Prof. Quan ZHOU from Shanghai University, Prof. Zhen-Yu YIN from The Hong Kong Polytechnic University, Prof. Fan XU from Fudan University, and Prof. Gang WANG from The Hong Kong University of Science and Technology. The conference also contains 10 parallel sessions with 55 presentations; 20 from Shanghai; 6 from Macau; and 29 from Hong Kong.

The Society appreciates all the speakers and contributors for their efforts to make this event a successful one. Special thanks go to Prof. Dong-qiang LU and Ms. Xiaoshuang HUANG of SSTAM for their great help in coordinating the conference on the Shanghai side; Mr. Yung-jeh CHU of City University of Hong Kong for his help in communicating various parties and editing this proceeding. The Society also wishes to thank the generous support from Institution Members of HKSTAM.

On behalf of and for the Executive Committee

Ir Prof Heung Fai LAM
President of HKSTAM
Chair Professor (Pengcheng Scholar, 鹏城学者), Harbin Institute of Technology, Shenzhen
Associate Professor, City University of Hong Kong

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Conference Program

December 5, Saturday, Morning [Chair: Prof Xinrui NIU, Zoom ROOM 1, https://cityu.zoom.us/j/91829576841?pwd=NCt0MXhQQkFNc01IWkd3ZkFHa0Qrdz09]

9:00 – 9:15am	**Opening addresses** **Professor Heung-fai LAM (林向暉)** **President of HKSTAM** **Professor Dong-qiang LU (卢东强)** **上海市力学学会 秘书长**
9:15 – 9:45am	**Distinguished Lecture I** **Professor Ming ZHANG (張明)** Department of Biomedical Engineering, Faculty of Engineering, The Hong Kong Polytechnic University, Hong Kong SAR **Biomechanical foot models for surgical treatments and foot support design**
9:45 – 10:15am	**Distinguished Lecture II** **Professor Quan ZHOU (周全)** Shanghai Key Laboratory of Mechanics in Energy Engineering, Shanghai Institute of Applied Mathematics and Mechanics, School of Mechanics and Engineering Science, Shanghai University, China **Heat Transport and Flow Structures in Vibrated Thermal Turbulence**
10:15 – 10:30am	**Break**
10:30 – 11:00am	**Distinguished Lecture III** **Professor Zhen-Yu YIN (尹振宇)** Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong SAR **Offshore caisson foundation in sand: from numerical modelling to macroelement design tool**

11:00 – 11:30am	**Distinguished Lecture IV** **Professor Fan XU (徐凡)** Department of Aeronautics and Astronautics, Fudan University, Shanghai, China **Morphomechanics of Growing Aquatic Plant Leaves**
11:30am – 12:00nn	**Distinguished Lecture V** **Professor Gang WANG (王剛)** Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong SAR **Physics-based large-deformation analysis of coseismic landslides: a multiscale MPM-SEM framework**
12:00nn – 2:00pm	**Break**

December 5, Saturday, Afternoon (Parallel Sessions A1 to A3)

	Session A1 **Chair: Prof Heung-fai LAM** **[Zoom ROOM 1:** https://cityu.zoom.us/j/91829576841?pwd=NCt0MXhQQkFNc01IWkd3ZkFHa0Qrdz09**]**	**Session A2** **Chair: Prof Hannah ZHOU** **[Zoom ROOM 2:** https://umac.zoom.us/j/91827129825?pwd=dWdBb2FIOXlrOWwvU2FYYVRKOTk0QT09**]**	**Session A3** **Chair: Prof Gang WANG** **[Zoom ROOM 3:** https://hkust.zoom.us/j/94553825698?pwd=NDcxbFhMdVpMY2RZVlpRSlBFbElzZz09**]**
2:00pm – 3:30pm			
2:00 – 2:15pm	F.L. Zhang, Y.X. Dong#*, Y. P. Yang, J.H. Yang and H.B. Xiong Bayesian model updating of a 250-m super-tall building utilizing an enhanced Markov chain Monte Carlo simulation algorithm	L.W. Zeng#, H.F. Wang* and C.Y. Zhao Effect of oncoming turbulence intensity on the flow around a finite-length square cylinder	王金瑞#，郑百林*，丛北华，张锴 NexGen 燃烧器标准火焰冲击平板数值模拟研究
2:15 – 2:30pm	M.O. Adeagbo*# and H.F. Lam A Bayesian extended sequential sensor optimization scheme for damage detection in ballasted tracks	Z.N. Chen# and C.Y. Wen* Flow Control of a D-Shaped Bluff Body Using Plasma Streamwise Vortex Generators	Z.T. Li#, H. Zhang and C.Y. Wen* Effects of tree planting on the in-canyon air quality and thermal comfort
2:30 – 2:45pm	J. S. Yang#, J.B. Chen* and H.A. Jensen An Efficient Method for Sensitivity Estimation of Failure Probability Based on the Probability Density Evolution Method	Chang HE#, Zhen-Yu YIN*, Wing-Hong WAI and Alessandro STOCCHINO Numerical modelling of tides and tidal currents in the Pearl River Estuary based on FVCOM	P. Pei# and Y.B. Peng* Molecular dynamics simulation based squeeze strengthening effect analysis of magnetorheological fluids
2:45 – 3:00pm	陈建兵*，律梦泽# 连续 Markov 过程时变极值分布的概率演化积分方程	Chunhui Ai# and Hui Tang* Fluid-structure interaction of compliant vessels with pulsatile flows	W. Yao# and G.H. Ding* A Model of Acupuncture Mechanical Effects
3:00 – 3:15pm	Qing Wang# and Xiaodan Ren* A multi-field model for early-age massive concrete structures: hydration, damage and creep	Wensen Zhang#, Feng Ren and Hui Tang* DMD analysis of non-Newtonian pulsatile flow in pathological vessels	Chao Qian# and Wenjing Ye* An adaptive network-based deep generative design method with applications to heat source layout design
3:15 – 3:30pm	Z.K. Zhang# and Y.B. Peng* A Dynamic Physical Model for MR Dampers	J.H. Yang, W.Y. Liu*# A Novel System Identification Method Based on Vector Autoregressive Moving Average Models	Wangqi Xu#, Zhenyu Yin* and Yuanyuan Zheng Molecular dynamics-based modelling of silica interface behavior
3:30 – 3:45pm	**Break**		

Note: # Presenter; * Corresponding author.

December 5, Saturday, Afternoon (Parallel Sessions A4 to A5)

	Session A4 **Chair: Prof Yang LU** **[Zoom ROOM 4:** https://cityu.zoom.us/j/94326263322?pwd=RWRHY0NnQVp0WlFyaXNLSXhQbUpKZz09]	**Session A5** **Chair: Prof Hui TANG** **[Zoom ROOM 5:** https://polyu.zoom.us/j/98583181950?pwd=aFNqTXI5OWtCcmQvOVBMWnFSOHM0UT09]
2:00pm – 3:30pm		
2:00 – 2:15pm	Yakang Jin#, Tiniao Ng, Ran Tao, Shuang Luo, Yan Su* and Zhigang Li* Coupling effects in nanoscale electromechanical ion transport	Pin Zhang# and Zhen-Yu Yin* A LSTM Surrogate Modelling Approach for Caisson Foundations
2:15 – 2:30pm	Chaoqun Dang# and Yang Lu* Nanomechanical characterization of tungsten microwire	Shunxiang Song#, Pei Wang and Zhen-Yu Yin* Investigation of particle size effect of granular materials through DEM
2:30 – 2:45pm	Sufeng Fan#, and Yang Lu* Size-dependent fracture behavior of GaN pillars under room temperature compression	H. Fan#, G. Wang* and D. Huang Simulating propagation of complex cracks in rocky masses by numerical manifold method
2:45 – 3:00pm	J.U. Surjadi#, X. Feng and Y. Lu* Microalloyed medium-entropy alloy (MEA) composite nanolattices with ultrahigh toughness and cyclability	Chengzeng Yan#, Tie Wang and Gang Wang* A coupled model for simulating desiccation-induced soil cracking
3:00 – 3:15pm	W.L. Xu# and B.L. Zheng* 基于有限元方法的轴向及横向载荷共同作用下的石墨烯变形研究	Kai Lou#, May Awarkeh, Zhen-Yu Yin* and Yu-Jun Cui Influence of dip angle on 1-D creep behaviour of natural clays
3:15 – 3:30pm	M. Ding#, Y. Cong, R. Li and F. Xu* Effect of surface topography on anisotropic friction of graphene layers	S. Mohajerani# and G. Wang* Peridynamics simulation of cemented granular materials using developed micro-mechanical models
3:30 – 3:45pm	**Break**	

Note: # Presenter; * Corresponding author.

December 5, Saturday, Afternoon (Parallel Sessions B1 to B3)

	Session B1 **Chair: Prof Heung-fai LAM** **[Zoom ROOM 1:** https://cityu.zoom.us/j/91829576841?pwd=NCt0MXhQQkFNc01IWkd3ZkFHa0Qrdz09**]**	**Session B2** **Chair: Prof Hannah ZHOU** **[Zoom ROOM 2:** https://umac.zoom.us/j/91827129825?pwd=dWdBb2FIOXlrOWwvU2FYYVRKOTk0QT09**]**	**Session B3** **Chair: Prof Gang WANG** **[Zoom ROOM 3:** https://hkust.zoom.us/j/94553825698?pwd=NDcxbFhMdVpMY2RZVlpRSlBFbElzZz09**]**
3:45 – 4:00pm	Y.J. Chu*# and H.F. Lam The Performance of a Flexible Flat-Bladed Wind Turbine: Numerical Approach	Z. Chen#, G. Wang and C.W. Lim* Active Phononic Crystal Beam on Elastic Foundation for Topologically Protected Flexural Wave Propagation	Wei Jiang# and Bailin Zheng* Study on Fast Cold Start-Up Method of Proton Exchange Membrane Fuel Cell Based on Different Heating Technology
4:00 – 4:15pm	Yupeng Song# and Jianbing Chen* Fatigue Analysis of a Floating Offshore Wind Turbine Subjected to Joint Wind and Wave Loads	X.B. Feng# and Y. Lu* Size-dependent mechanical properties of low-stacking fault energy multi-component alloys at small scales	Y. Yang#, C. Fu and F. Xu* A finite strain model predicts oblique wrinkles in stretched anisotropic film
4:15 – 4:30pm	B.R. Wen#, Z.H. Jiang, X.L. Tian* and Z.K. Peng Unsteady Aerodynamics of Floating Wind Turbine: an Experimental Study	S. Luo#, J. Wang* and Z. Li* The Role of Shear in Ice Crystallization	Zan. Zhou# and M. H. Lok* An Improved General Regression Neural Network to Analyze the Spatial Variability of SPT in Soil Layer
4:30 – 4:45pm	方若诗#，郑百林*，宋珂，张锴，徐咏川 燃料电池低温快速启动中冰及构件的非傅里叶热传导和热应力分析	F. Xu*, S. Zhao#, C. Lu and M. Potier-Ferry Pattern formation in core-shell spheres	Tao Yu and Jidong Zhao* A semi-coupled resolved CFD-DEM method for simulation of Selective Laser Melting
4:45 – 5:00pm	Shengyang CHEN# and Chih-Yung WEN* FLVIS: A Novel Pose Estimation Approach for Aerial Robots	W.P. Wu# and W.H. Zhou* Research on characteristics of solidified clay produced by flocculant-dredged slurry based on bender element test	Z.H. Shen#, G. Wang*, D. Huang and F. Jin Resolved CFD-DEM coupling for modelling two-phase fluids interaction with irregularly shaped particles
5:00 – 5:15pm	**Break**		

Note: # Presenter; * Corresponding author.

December 5, Saturday, Afternoon (Parallel Sessions B4 to B5)

	Session B4 **Chair: Prof Yang LU** **[Zoom ROOM 4:** https://cityu.zoom.us/j/94326263322?pwd=RWRHY0NnQVp0WlFyaXNLSXhQbUpKZz09]	**Session B5** **Chair: Prof Hui TANG** **[Zoom ROOM 5:** https://polyu.zoom.us/j/98583181950?pwd=aFNqTXI5OWtCcmQvOVBMWnFSOHM0UT09]
3:45 – 5:00pm		
3:45 – 4:00pm	R. Tao#, Y. Jin and Z. Li* An efficient microfluidic rectifier for Newtonian fluids based on asymmetric converging-diverging microchannels	R. Zhang# and J. Yang* Micromechanical Investigation of the At-rest Earth Pressure Coefficient of Granular Soil
4:00 – 4:15pm	L.H. Gao#, W.W. Deng* and H. Tang* Experimental Study of Liquid Micro Jets ablated by Nanosecond Laser Pulse	S. Qin#, W.H. Zhou*, Z.L. Cheng and T. Xu Estimation model of excess pore water pressure in front of a TBM in saturated sand
4:15 – 4:30pm	Y.Z. Peng#, K. Zhang and B.L. Zheng* Diffusion-induced stresses in a thin film electrode on an elastic substrate in lithium ion batteries	Y.Z. Chen# and W.H. Zhou* Geotechnical and microstructural properties of marine clay treated by nano zero-valent iron (nZVI)
4:30 – 4:45pm	徐咏川#, 郑百林*, 宋珂, 张锴, 方若诗 PEMFC 快速冷启动时催化层内球形冰粒的非傅立叶热传导及热应力分析	Quan Ku#*, Bo Zhou and Jidong Zhao Characterization of Microstructure and Particle Breaking of Carbonate Sand
4:45 – 5:00pm	Z. Cheng# and F. Xu* Intricate evolutions of multiple-period post-buckling patterns in bilayers	Z. Lu#, W.H. Zhou* and Z.Y. Yin Numerical modelling of slurry infiltration in granular materials
5:00 – 5:15pm	**Break**	

Note: # Presenter; * Corresponding author.

December 5, Saturday, Evening

5:15 – 6:15pm	**HKSTAM Annual General Meeting** **[Zoom ROOM 1:** https://cityu.zoom.us/j/91829576841?pwd=NCt0MXhQQkFNc01IWkd3ZkFHa0Qrdz09**]** Attendees: Representatives of Institution Members and Full HKSTAM members

~ Closure of the conference ~

Distinguished Lecture I

Ming ZHANG (張明)

Ming ZHANG is professor and head of Department of Biomedical Engineering, The Hong Kong Polytechnic University. He received his BSc in automation control engineering, MSc in mechanical engineering, from Beijing Institute of Technology, and PhD in medical engineering from King's College, University of London in 1995. He is Councillor of World Council of Biomechanics (WCB), President of the World Association for Chinese Biomedical Engineers (WACBE), Chair of Chinese Rehabilitation Engineering Committee, Visa President of Chinese Rehabilitation Devices Association, Standing Council member of Chinese Society of Biomedical Engineering, Fellow of Biomedical Division of Hong Kong Institute of Engineers. He serves as Proposal Selection Panel Member for NSFC China and Hong Kong Research Grant Council. His research interests include biomechanics of musculoskeletal system and body support, computational biomechanics, tissue biomechanics, foot biomechanics and footwear design, prosthetic and orthotic bioengineering, and human motion and body vibration analysis. Prof Zhang has won a number of international awards, including the Natural Science Award (First-class) of the 2015 Higher Education Outstanding Scientific Research Output Awards by the Ministry of Education, and The Hong Kong Polytechnic University President's Awards for Excellent Performance/Achievement in Research and Scholarly Activities 2016.

Biomechanical foot models for surgical treatments and foot support design

Ming Zhang
Department of Biomedical Engineering, Faculty of Engineering, The Hong Kong Polytechnic University
*Corresponding author: Tel: +852 2766 4939, E-mail: ming.zhang@polyu.edu.hk
Presenter: E-mail: ming.zhang@polyu.edu.hk

Abstract: Foot and ankle is an intricate and synergetic system with very complex structures. The foot and ankle problems have become a major burden on public healthcare systems and have significant impacts on the quality of the life. Most foot-ankle diseases, deformities and injuries are related to mechanical loading. Biomechanical information on the internal structures as well as foot-support interfacial load transfer during various activities is useful in enhancing our biomechanical knowledge for footwear design and clinical treatments. We developed multi-scale computational biomechanical models of foot and ankle including musculoskeletal model and finite element analyses. Human motion analysis system was conducted to obtain the kinematic and kinetic information during walking, running or other sports activities. Musculoskeletal model was developed to estimate the muscle and joint forces. Three-dimensional geometrically accurate finite element (FE) models of the foot and ankle structures include 28 separate bones, 103 ligaments and the plantar fascia, embedded in a volume of encapsulated soft tissue. The main bone interactions were simulated as contact deformable bodied. The analyses took into consideration the nonlinearities from material properties, large deformations, interfacial slip/friction conditions, and dynamic effects. Experiments on human subjects and cadavers were conducted to validate the models. The validated models will be used for parametric studies to investigate the biomechanical effects of tissue stiffness, muscular reaction, surgical and orthotic performances on the foot and ankle complex. The platform allows 1) to understand foot-ankle biomechanics and pathomechanics for foot-ankle diseases, deformities and trauma; 2) to associate the biomechanical effect such as stress/strain with the biological effect including blood flow and muscle oxygen; and 3) to establish a platform for understanding the consequence of surgical and orthotic intervention, so as to provide scientific guidance to surgical treatment, implant and orthosis design.

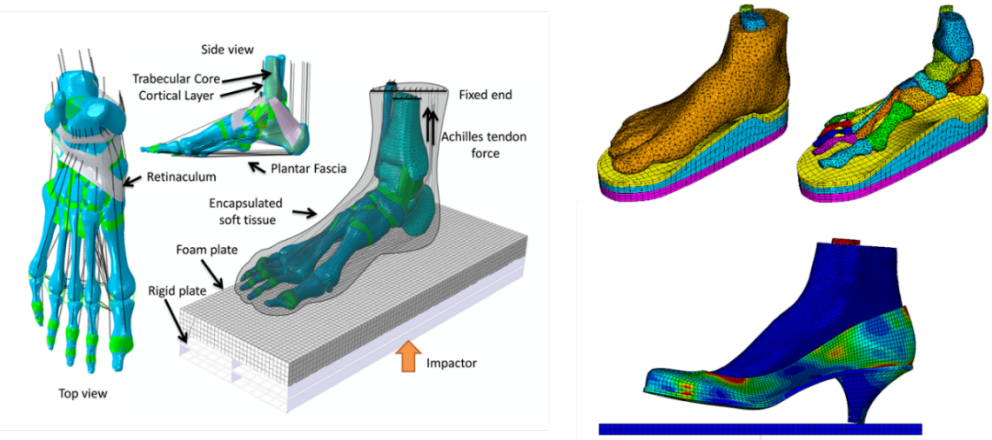

Figure 1. Computational Foot and ankle model and its application in foot support design

Acknowledgements

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Distinguished Lecture II

Quan ZHOU (周全)

周 全，男，1981 年出生，教授，国家杰出青年科学基金获得者，上海大学力学与工程科学学院副院长、上海市应用数学和力学研究所副所长、上海市能源工程力学重点实验室副主任。2003 年于中国科学技术大学获学士学位，2005 年和 2008 年于香港中文大学分别获硕士和博士学位。主要研究方向为湍流和热对流，已在 ***Science Advances***、***Physical Review Letters***、***Journal of Fluid Mechanics*** 等期刊上共发表 SCI 论文 40 余篇。现担任中国力学学会第九届青年工作委员会委员和第十三届实验流体力学专业组组员、上海市非线性科学研究会副理事长、上海力学学会第十三届理事会理事和青年工作委员会主任、***Applied Mathematics and Mechanics***、***Scientific Reports***、***Journal of Hydrodynamics*** 等期刊编委、《实验流体力学》和《空气动力学学报》青年编委。2018 年获得“国家杰出青年科学基金项目”资助，2020 年作为第一完成人获得上海市自然科学二等奖。

Heat Transport and Flow Structures in Vibrated Thermal Turbulence

Quan Zhou

Shanghai Key Laboratory of Mechanics in Energy Engineering, Shanghai Institute of Applied Mathematics and Mechanics, School of Mechanics and Engineering Science, Shanghai University, Shanghai 200072, China.

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Presenter: E-mail: zhou@shu.edu.cn

Abstract: Thermal turbulence is well known as a potent means to convey heat across space by a moving fluid. The existence of the boundary layers near the plates, however, bottlenecks its heat-exchange capability. Here, we conceptualize a mechanism of thermal vibrational turbulence that breaks through the boundary-layer limitation and achieves massive heat-transport enhancement. When horizontal vibration is applied to the convection cell, a strong shear is induced to the body of fluid near the conducting plates, which destabilizes thermal boundary layers, vigorously triggers the eruptions of thermal plumes, and leads to a heat-transport enhancement by up to 600%. We further reveal that such a vibration-induced shear can very efficiently disrupt the boundary layers, and as a result the asymptotic ultimate scaling of heat transport would show up at high vibration frequencies. The present findings open a new avenue for research into heat transport and will also bring profound changes in many industrial applications where thermal flux through a fluid is involved and the mechanical vibration is usually inevitable.

Distinguished Lecture III

Zhen-Yu YIN (尹振宇)

Zhen-Yu YIN is Associate Professor of Geotechnical Engineering at The Hong Kong Polytechnic University since 2018. Dr. Yin received his BEng in Civil Engineering from Zhejiang University in 1997, followed by a 5 years engineering consultancy at the Zhejiang Jiahua Architecture Design Institute. Then, he obtained his MSc and PhD in Geotechnical Engineering at Ecole Centrale de Nantes (France) in 2003 and 2006 respectively. Then he has been working as postdoctoral researcher at Helsinki University of Technology (Finland), University of Strathclyde (Glasgow, UK), Ecole Centrale de Nantes and University of Massachusetts (Umass-Amherst, USA). In 2010 he joined Shanghai Jiao Tong University as the "Professor of Exceptional Rank of Shanghai Dong-Fang Scholar" by the Shanghai Municipal Education Commission. In 2013 he joined Ecole Centrale de Nantes as Associate Professor before moving to Hong Kong in 2018. Dr. Yin has published over 170 articles in peer reviewed international journals with an H index of 36 according to Web of Science. He is an Associate Committee Member of the granular materials committee of American Society of Civil Engineers, Editorial Board Members of some top journals in the field of geomechanics and geotechnics (e.g., International Journal of Geomechanics ASCE, Acta Geotechnica, Soils and Foundations, Canadian Geotechnical Journal).

Offshore caisson foundation in sand: from numerical modelling to macroelement design tool

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Abstract: This work deals with the response of caisson foundations in sand for offshore wind turbines submitted to combined monotonic and cyclic loadings. First, the failure process and failure envelope (or bearing capacity diagram) of a caisson foundation in sand under combined monotonic loadings is numerically investigated. A Combined Lagrangian-Smoothed Particle Hydrodynamics (CLSPH) method is adopted to consider large deformation. A recently developed critical state model for sand (SIMSAND) is then introduced and combined with the CLSPH method. Different parameters affecting the shape and size of the failure envelope are considered, as soil density and stiffness, friction strength, grain breakage, geometry and aspect ratio of the foundation. An analytical formula is introduced to describe the 3D failure surface reproducing the numerical results. Based on the proposed analytical formula, a macroelement for the caisson foundation in sand submitted to monotonic and cyclic loadings is finally developed within the framework of hypoplasticity. Validation is provided through comparison with experimental results.

Acknowledgements
The author would like to thank the Hong Kong Research Grant Council for the support of his research.

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Distinguished Lecture IV

Fan XU (徐凡)

Dr. Fan XU is a Professor at Fudan University. His research interests include mechanics and physics of thin films, soft matters, smart materials and slender structures. He has published more than 40 papers in SCI journals such as PRL, JMPS, Nature Biomed. Eng., AFM, IJSS, IJES, EML and Science China Phys. Mech. Astro., *etc*. His researches were highlighted by Nature, Nature Physics, Nature Biomed. Eng., and selected as cover image by PRL. He received the ASME Prize (French section) in 2016, and was selected as "Ten Emerging Star Scientists in China" in 2018.

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Morphomechanics of Growing Aquatic Plant Leaves

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Abstract: Having waves in morphological pattern is energetically favorable for thin living tissues such as leaves, flowers, and biological membranes, where spontaneous symmetry breaking induced by differential growth is normally considered as a significant factor in the origin of such complex patterns. Growth-induced morphogenesis can be affected by many elements including intrinsic (e.g., gene) and external (e.g., phototropism) ones. Lately, we have observed that water can dramatically alter the morphogenesis of lotus leaves in the same plant, where the ones floating on water demonstrate flat geometry with short-wavelength wrinkles on the edge, while the leaves growing above water usually morph into a bending cone shape with long rippled waves near the edge (see Fig. 1). Such a phenomenon reveals the interplay between internal growth-induced residual stresses and external support from the water (liquid substrate), which affects the morphogenesis of growing tissues. Besides, other influencing factors, such as mechanical constraints from the stem or vein, heterogeneity-induced growth curvature and size effect (see Fig. 1), can alter the shape of leaves. Understanding growth-triggered morphological evolution and in particular the dependence of wrinkling behavior on liquid foundation can help design biomimetic deployable structures that quantitatively harness surface instabilities using substrate or edge actuation for environment adaption and camouflage.

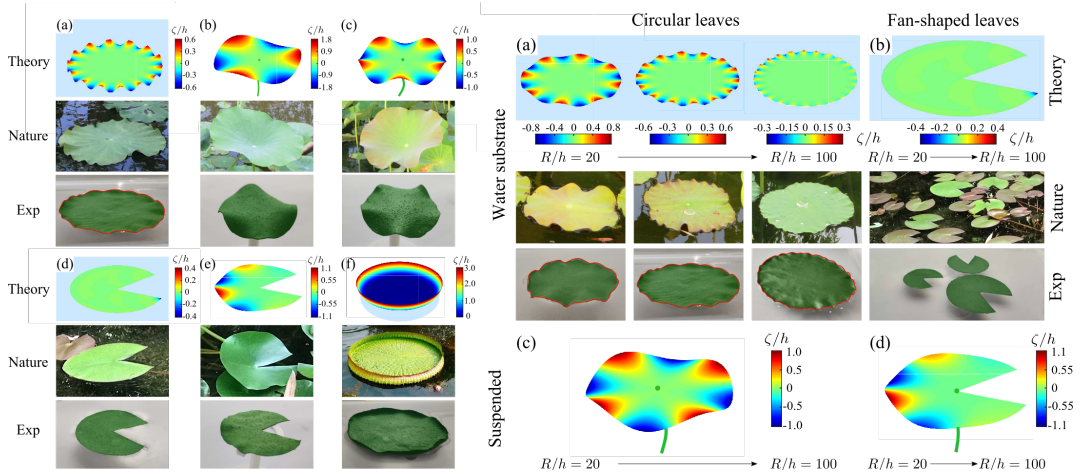

Figure 1. The left side indicates water effect on morphogenesis of diverse aquatic plant leaves. The right side illustrates size effect (*R/h*) on growing shapes of lotus (circular) and white water lily leaves (fan-shaped).

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This work is supported by the National Natural Science Foundation of China (Grant No. 11872150) and Shanghai Rising-Star Program (Grant No. 19QA1400500).

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Distinguished Lecture V

Gang Wang (王剛)

Dr. Gang Wang is Professor of Civil and Environmental Engineering at the Hong Kong University of Science and Technology. His major research interests are geotechnical earthquake engineering, soil dynamics and computational geomechanics. He obtained B.Eng. and M. Eng. from Tsinghua University in 1997 and 2000, respectively, and Ph.D. in from University of California, Berkeley in 2005. He is Vice President and incoming President of Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM), Invited Council Member of Chinese Society of Theoretical and Applied Mechanics (CSTAM), member of TC203 Technical Committee for Geotechnical Earthquake Engineering of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), Past President of ASCE Hong Kong Section. He published more than 70 research papers in reputable SCI journals, and presently is Associate Editor of Soil Dynamics and Earthquake Engineering, Advances in Structural Engineering, CMES-Computer Modeling in Engineering & Sciences. He was awarded Chinese Government Award for Outstanding Self-financed Students Abroad (2004), Li Foundation Heritage Prize (2010), HKUST School of Engineering Distinguished Teaching Award (2018), Mao Yisheng Youth Award (2018) by Chinese Institution of Soil Mechanics and Geotechnical Engineering, NSFC Joint Research Award for Oversees Chinese Scholars and Scholars in Hong Kong and Macau (2018). Three of his supervised Ph.D. students and Postdoc are enlisted into "National Thousand Youth Talents Program".

Physics-based large-deformation analysis of coseismic landslides: a multiscale MPM-SEM framework

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Abstract: Coseismic landslides are complicated nonlinear, progressive, large-deformation processes triggered by ground shaking. To date, analytical methods for estimating coseismic landslides have been based on highly simplified models. In this paper, we develop a multiphase Material Point Method (MPM), which is coupled with Spectral Element Method (SEM) for multi-scale, large-deformation analysis of coseismic landslides. At the regional scale, SEM is efficient in modeling a 3D wave field in complex topography on a scale of hundreds of kilometers. At the local scale, the progressive slope failure process and post-failure large-deformation behaviour, including triggering, runoff and deposition of landslide masses, is studied by MPM. The multiscale MPM-SEM method is the first numerical tool of its kind for an integrated study of the complete coseismic landslide process. Several numerical case studies, including Hongshiyan landslide triggered by the 2014 Ludian earthquake in China, are presented.

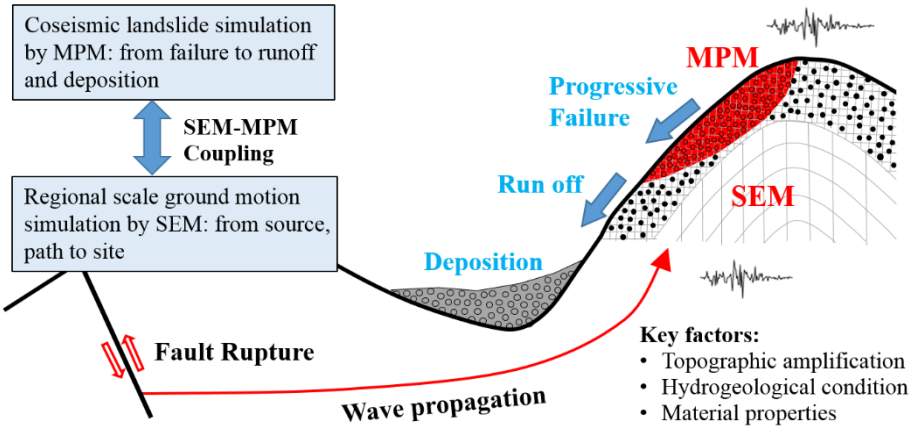

Figure 1: Framework of the multiscale MPM-SEM for coseismic landslide simulation

Acknowledgements
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Bayesian model updating of a 250-m super-tall building utilizing an enhanced Markov chain Monte Carlo simulation algorithm

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Abstract: Finite element mode (FEM) could provide an effective way to predict the structural behavious subjected to the impact excitation. In the establishment of FEM, some modelling errors always exist to affect the accuracy of the model, especially for complex structural systems. Model updating based on the measured structural responses could improve the accuracy significantly since it could well combine the numerical model and the test results. In this work, the field vibration tests model updating of a 250-m tall structure building were presented by the enhanced Markov chain Monte Carlo (MCMC) based Bayesian method. In this method the procedure is divided into multiple levels and the bridge probability density function (PDF) is constructed to approach the target PDF in each level. Kernel density simulation is used in previous level samples. Thus, samples generated from the kernel density of the samples in previous level will move to the important region smoothly level by level to approximate the posterior marginal PDF in the final level. Sensitivity analysis was carried out to investigate the efficiency of the model updating through the algorithm presented. The model updating with different numbers of uncertain parameters, initial samples of each parameter, speed to the important regions in each level and sampling levels are discussed to study the performance of the algorithm on the application of the super-tall building.

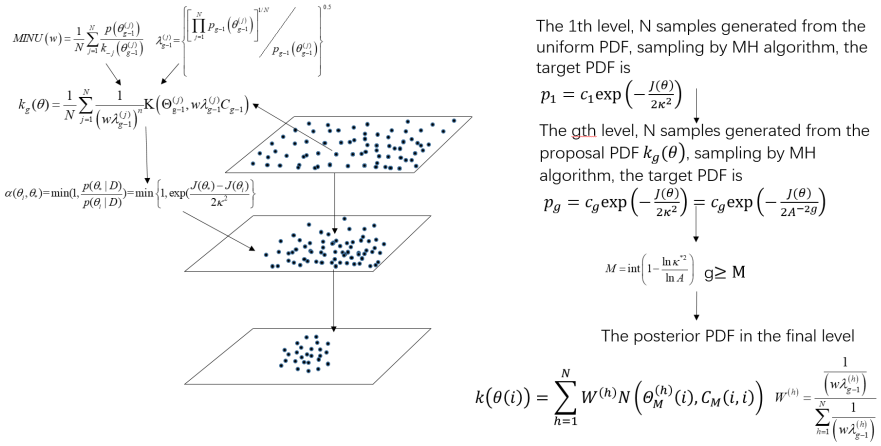

Figure 1. Procedure of the algorithm

Acknowledgements

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A Bayesian extended sequential sensor optimization scheme for damage detection in ballasted tracks

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Abstract: The problems of sensor placement and evaluation are well-known in structural health monitoring. In this study, an extended sequential sensor optimization scheme for sensor placement, which is more robust and effective than conventional methods, was developed. Using the information entropy as the measure of optimality in candidate configurations, the proposed scheme implements Bayes theorem and MCMC samples to evaluate optimality. Moreover, novel optimality indices were developed to compare the efficiency of sensor configurations having the same number of sensors or otherwise. The proposed optimization scheme efficiently addresses the large computational demand involved in some existing techniques. Although relatively cheap in its demand, the proposed scheme's efficiency is improved by ensuring that alternative configurations to the optimal one are available for a given number of sensors. Most sensor optimization scheme involving information entropy suffers from sensors been placed too close to each other, leading to information redundancy. This problem of information redundancy is addressed by enforcing a minimum distance between sensors, as well as the spatial correlation of prediction error at the observed degrees-of-freedom. The proposed scheme is implemented in the damage detection of a ballasted track system. The optimal configuration obtained with the proposed scheme at a various number of sensors is compared with popular conventional ones, and the superiority of the proposed method in terms of system information is established. Furthermore, for verification purposes, the optimal configurations obtained with each of the optimization schemes been compared were used to predict the location and severity of ballast damage in a ballasted track panel, using experimentally measured acceleration data. The results demonstrate the better reliability and practicality of the proposed scheme for sensor placement, especially in field applications, compared to conventional methods.

Acknowledgments

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An Efficient Method for Sensitivity Estimation of Failure Probability Based on the Probability Density Evolution Method

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Abstract: Reliability-based design optimization (RBDO) is a practical framework to explicitly consider uncertainties in structural optimization. In general, reliability analysis and sensitivity estimation account for the greatest part of computational efforts. The probability density evolution method (PDEM) provides a unified and highly efficient tool for reliability analysis of both linear and nonlinear structures. In the present paper, a new method is proposed based on the PDEM to estimate the sensitivity of failure probability. In the proposed method, the sensitivity is first approximated by the finite difference scheme. The failure probabilities at perturbed designs are estimated by shifting the threshold of failure at each representative point. In order to obtain the changes of the thresholds of failure, a small number of structural analyses are performed and a surrogate model is employed. Finally, a few numerical examples are included to show the effectiveness and validity of the proposed method. A dynamic reliability-based design optimization problem is also solved by incorporating the PDEM and the proposed sensitivity estimation method into the globally convergent method of moving asymptotes. Numerical results indicate that the proposed method can estimate the sensitivity of failure probability with high accuracy in an efficient manner.

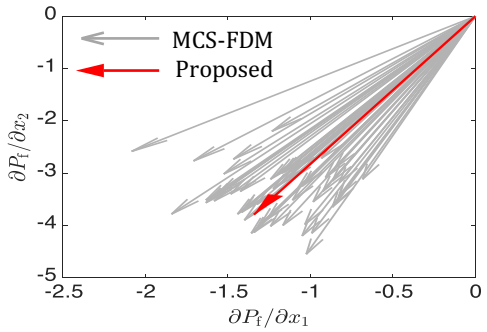

Figure 1. Comparison of the proposed method and Monte Carlo simulation-based sensitivity estimation method

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连续 Markov 过程时变极值分布的概率演化积分方程

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摘要: 研究 Markov 过程的时变极值过程在科学与工程领域有着重要的意义. 例如，对于随机动力系统的首次超越问题的求解即可转化为上述问题 (Li & Chen 2009). 然而，长期以来仅有极少数特殊过程的极值分布解析表达已知 (Molini et al. 2011)，一般情况下则需要采用数值方法求解，例如构造极值-状态量联合 Markov 向量过程的方法 (Chen & Lyu 2020). 本文从首次超越时间的角度出发，对于一般的连续 Markov 过程 $X(t)$，推导了在给定初值 x_0 下，其时变极值过程 $Z(t)$ (样本路径如图 1 所示) 的概率演化积分方程 [式(1)]，其中 $F_Z(x,t)$ 表示极值过程 $Z(t)$ 的概率分布函数 (CDF)，$F_X(x,t|x',\tau)$ 表示过程 $X(t)$ 的条件概率分布. 根据这一方程，若已知原过程的概率分布信息，则可以解析或数值地获得其时变极值过程的概率分布信息，进而应用于首次超越破坏问题的求解. 最后，本文通过算例与蒙特卡罗模拟 (MCS) 的对比，验证了概率演化积分方程求解结果的正确性 (如图 2 所示).

$$F_Z(x,t)+2\int_0^t F_Z(x,\tau)\frac{\partial F_X(x,t|x,\tau)}{\partial\tau}\mathrm{d}\tau=2\left[F_X(x,t)-F_X(x,t|x,0)\right],\ x\geq x_0 \quad (1)$$

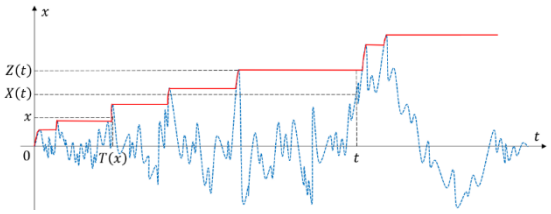

图 1. 连续过程与其时变极值过程的样本轨迹

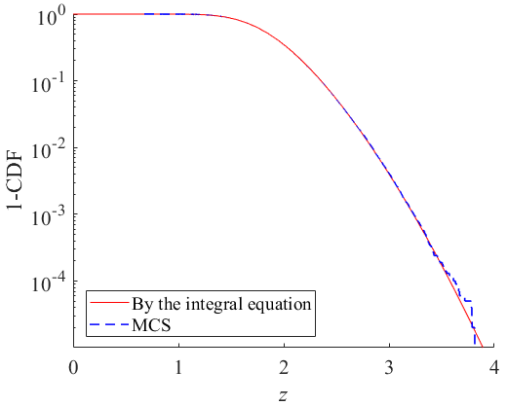

图 2. 概率演化积分方程的结果与 MCS 的对比

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A multi-field model for early-age massive concrete structures: hydration, damage and creep

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Abstract: In this work, a multi-field model for early-age massive concrete structures is proposed. It simultaneously takes consideration of hydration, thermal deformation, damage, creep and shrinkage strains, where the hydration process and the thermal evolutions are both described by a coupled chemo-thermal model. And the damage-plasticity model proposed by Wu et al. (2006) and Ren et al. (2015) is adopted to consider the instantaneous plasticity and damage effect. For the creep strain, the extended microprestress-solidification theory proposed by Rahimi-Aghdam et al. (2019) is implemented to account for the effects of stress, temperature and degree of hydration. To account for nonlinear creep at relatively high stress, a damage-dependent nonlinear creep function is introduced to couple damage and creep. And the autogenous shrinkage and thermal strains at early age are characterized by linear functions of degree of hydration and temperature, respectively. Moreover, the early-age evolutions of strengths and peak strains are modelled with functions of hydration degree to characterize the aging effect. Systematic numerical simulations including simple creep tests and a three-dimensional finite element analysis of a massive concrete wall are carried out to validate the model. Numerical results suggest that the proposed model offers promise for the analysis of early-age cracking within massive concrete structures.

Acknowledgements

The authors wish to thank the guidance of Professor Roberto Ballarini.

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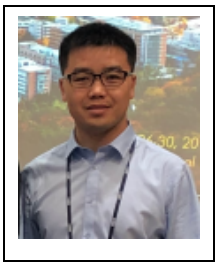
A Dynamic Physical Model for MR Dampers



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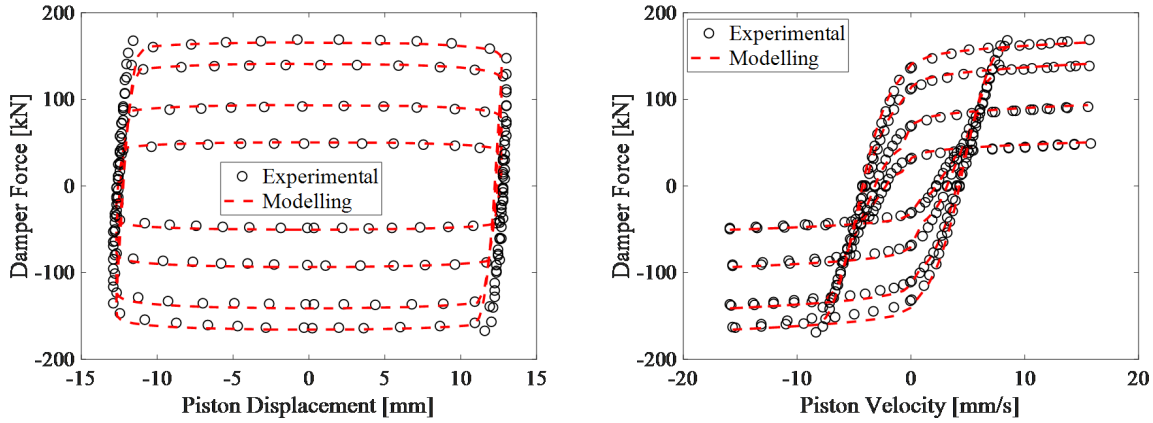
Abstract: A novel dynamic physical model for MR dampers is proposed. In this model, the hysteretic properties are considered to result from the difference between the working mechanism of MR fluids in their pre-yield and post-yield stages. In the pre-yield stage, the MR damper's force is caused from the chain deflection of MR fluids, which can be described by a particle-chain model. However, in the post-yield stage, the MR damper's force is caused from the flow gradient of MR fluids, which can be accurately predicted by the quasi-static model. Therefore, the proposed model is a combination of particle-chain model and quasi-static model. The input-current dependence and loading-condition dependence of MR damper are then addressed. By establishing the relationship between model parameters and input current, the input-current dependence is solved. By analyzing the physical mechanism of the proposed model and its consistency with experimental data, the relevance with the loading amplitude and frequency is revealed. For the purposes of validation, comparative studies between the proposed physical modelling result and experimental data with different loading conditions are analyzed. Numerical results show that the proposed model enables a high-accurate description on MR damper's hysteretic properties.



(a) Force-velocity relationship (a) Force-velocity relationship

Figure 1. Comparison between modelling result and experimental data

Acknowledgements

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Effect of oncoming turbulence intensity on the flow around a finite-length square cylinder

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Abstract: An experimental investigation was conducted to study the aerodynamic and flow field characteristics of a finite-length square cylinder. Three different turbulence flow, namely uniform flow conditions, 5% and 12% turbulent flow, were selected. The aspect ratio of the square cylinder was 5 and the Reynolds number based on the free-stream velocity and the width of the model was around 34000. Besides, flow around finite-length square cylinder under different oncoming turbulence has been compared with a two-dimensional one. The results showed that the aerodynamic forces, Reynolds stress, and the strength of first-third-order POD modes' vorticity increased with the increased turbulence for the finite-length square cylinder. In contrast, the two-dimensional one exhibited the opposite rule. The reason is that the probability of anti-symmetry in the wake will increase as the increased turbulence intensity for a finite-length square cylinder, while the two-dimensional cylinders vortex intensity may become weaker as the turbulence intensity increases.

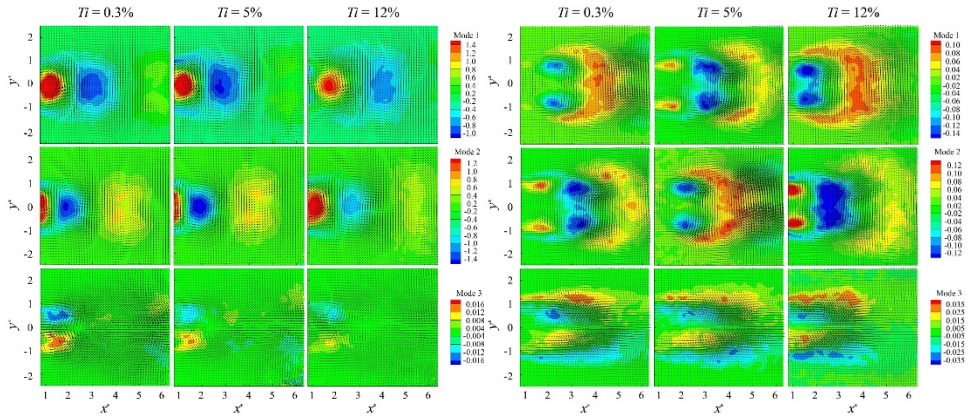

Figure 1. Flow structures of 1-3 POD modes in a 2-D(left-hand) and finite-length square cylinder (right-hand)

Acknowledgements

The authors wish to thank national natural science foundations of China(11472312, U1534206).

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Flow Control of a D-Shaped Bluff Body Using Plasma Streamwise Vortex Generators

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Abstract: The control performance of and a hybrid dielectric barrier discharge (DBD) plasma actuator on the reduction of a D-shaped bluff-body flow separation and wake fluctuation is experimentally investigated, comparing with a traditional DBD plasma actuator and a set of plasma streamwise vortex generators (PSVGs). Experiments are conducted in a low-speed and low-turbulent-level wind tunnel between a chord Reynolds number of 5000 to 10000. Particle image velocimetry (PIV) is used to obtain the details of the flow fields over a D-shaped bluff body. Meanwhile, force measurement is conducted to compare the reduction of drag by using these three types of plasma actuators and the power consumption is captured to explore the efficiency of different actuators. The results show that all plasma actuators suppress the flow separation on the bluff body, reduce the size of the wake, and decrease the wake fluctuations. A comparison of three types of DBD actuators shows that hybrid actuator achieve better control performance on the reduction of the recirculation bubble sizes and turbulence kinetic energy (TKE) in the wake at low speed because the it generates stronger three-dimensional flow structures on the bluff body which enhances the mixing consequently. The results suggest that hybrid DBD plasma actuators are promising in the wake flow control at low speed for bluff bodies.

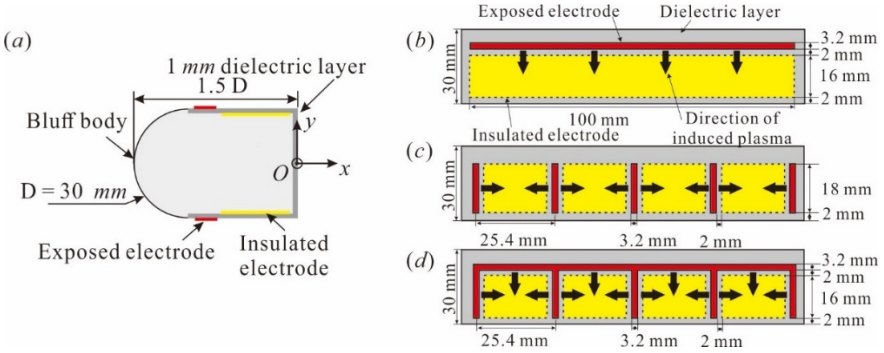

Figure 1. (a) Schematic of the half-cylindrical head cylinder. Configurations of (b) a traditional DBD plasma actuator, (c) PSVGs, and (d) the hybrid DBD plasma actuator.

Acknowledgements

The authors are grateful for the financial support provided by the US Office of Naval Research Global (contract no. N62909-16-1-2161).

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Numerical modelling of tides and tidal currents in the Pearl River Estuary based on FVCOM

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Abstract: The Finite-Volume Coastal Ocean Model (FVCOM) (Chen et al., 2003) is used to simulate the dynamics of the circulation in the Pearl River Estuary (PRE). The computation domain (21.0-23.0°N, 112.8-115.0°E) covers the main part of the Pearl River Estuary with 8 major inlets and waters around Hong Kong. The horizontal grids have spatial resolutions that vary from 0.1 km to 10 km over the entire domain, with 0.1–0.3 km near Hong Kong, and 10 km close to the open boundary. River discharge, wind, and tides were implemented on the open boundary. The simulation agreed well with the elevation data from the Hydrographic Office in Hong Kong. Additionally, sensitivity runs that include up-estuary and /or down-estuary winds were also implemented. Simulations were compared between wet and dry seasons in 2017, with coastal current flowing eastward during summer and westward during winter. This study reveals the physical mechanism of the wind and tides affecting the circulation in Pearl River Estuary.

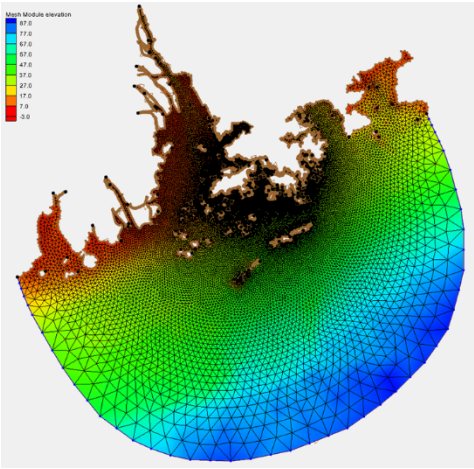

Figure 1. Model domain and grids for FVCOM in Pearl River Estuary.

Acknowledgements

The work was supported by an RIF project of Research Grants Council (RGC) of Hong Kong (Ref No. R5037-18F).

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Fluid-structure interaction of compliant vessels with pulsatile flows

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Abstract: Cardiovascular diseases have been one of the leading causes of death in the world, usually involving pathological alterations in blood vessels. Some vascular diseases are related to anomalies in vessel geometry, such as arterial aneurysm and arterial stenosis. Many studies have been conducted on this type of problems from the perspective of fluid dynamics, most are simulation work though. Compared to simulations, experimental investigations on vascular models are more challenging, considering the possibly large deformation of vessels and the unsteadiness of the flow. Furthermore, most of existing studies only focus on rigid vessel models. Hence, in the present work, we experimentally studied the interaction between various deformable vascular models and the inside pulsatile flow. Three sets of simplified, compliant, transparent vascular models were built using silicone: one straight, one with a bulge, and one with a stenosis. The flexibility of these vascular models was adjusted by changing the vessel thickness and controlling the curing temperature during manufacturing. The pulsatile flow was produced using a programmable pump, in a physiological waveform similar to that in human bodies. With time-resolved PIV measurements, the unsteady flow field inside the model are obtained along with the deformation of the vessel wall. Measurements on rigid models made of glass were also conducted for comparison. Some interesting results will be presented in the talk.

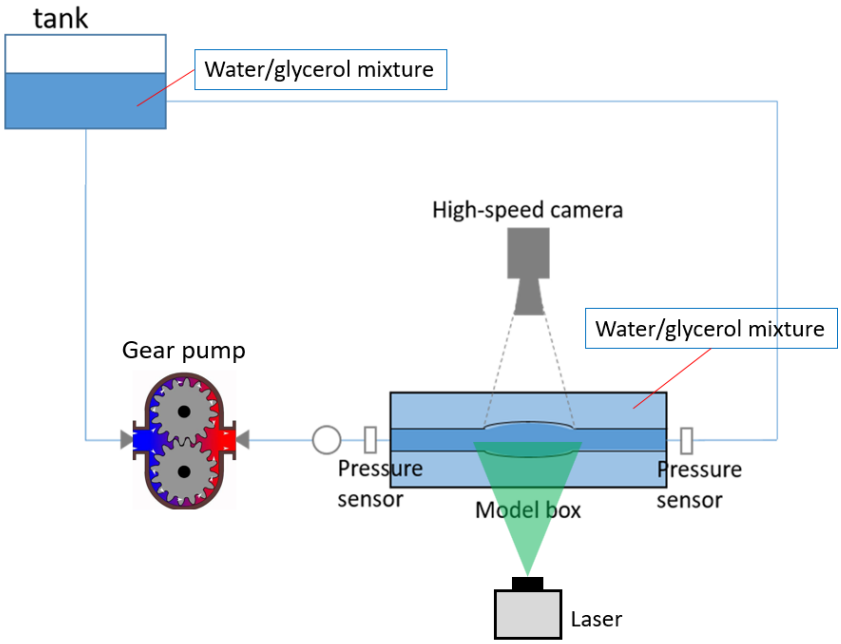

Figure 1 Experimental Set up

DMD analysis of non-Newtonian pulsatile flow in pathological vessels

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Abstract: Cardiovascular disease (CVD) involves geometrical change of blood vessels. To explore of the potential relation between abdominal aortic aneurysms (AAA) and aortic atherosclerosis (AS), three-dimensional numerical simulations are conducted on non-Newtonian pulsatile flow in pathological vessels. The immersed-boundary-lattice-Boltzmann-method (IB-LBM) is employed to obtain the unsteady flow fields, as well as the temporal and spatial distribution of wall shear stress (WSS), with the Reynolds number varying between 20 and 1173 and Womersley number being fixed at 10.5. Comparisons are made in the characteristic flow phenomena and corresponding WSS distribution between the pathological and healthy vessels. It is found that in stenosed vessels, the flow is characterized by the vortices produced in stenosed region that can propagate downstream, whereas in bugling vessels, vortices are obviously diffused in the distal region. Coherent flow structures are extracted using dynamic mode decomposition (DMD) method, which suggest that the second DMD mode significantly contributes to the rise of WSS in the systolic phase of the cardiac cycle. The current research provides more physical insights into connection between pulsatile flow and the associated WSS in pathological vessels.

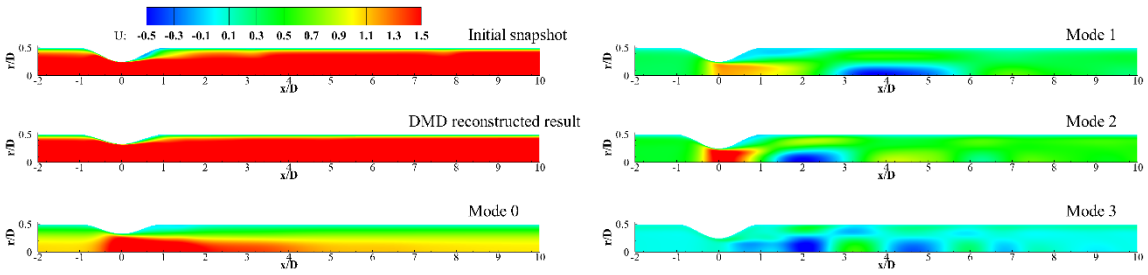

Figure 1. DMD results of 75% severity stenosed vessel in the systolic phase of the cardiac cycle (t = 0.22T)

Acknowledgements

This research is supported by the Research Grants Council of Hong Kong under General Research Fund (No. 15214418)

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A Novel System Identification Method Based on Vector Autoregressive Moving Average Models

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Abstract: System identification is a process that mathematical models are estimated from measured data, so that the predicted responses by the identified models can fit the measured data. For full-scale structures, it will be convenient and efficient to identify models in a simple mathematical form without constructing complicated finite element models. A vector autoregressive moving average model (VARMA) fits this purpose. It has a simple linear structure that provides us the advantage of working on measured data directly. This paper proposes a novel system method using VARAMA models. First, the connection between the equation of motion of a structural system and a VARMA model is established. Second, the state-space model is constructed based on the equation of motion, and then transformed to the VARMA model for free vibration or forced vibration under ambient excitations. Third, the relationship between the eigenvalue problems of the VARMA parameter matrices and the structural system is established for extracting modal parameters from a VARMA model given measured data. Finally, the system identification is formulated into a optimization problem with modal parameters as the uncertain parameters. A fast algorithm is developed for this high-dimensional optimization problem.

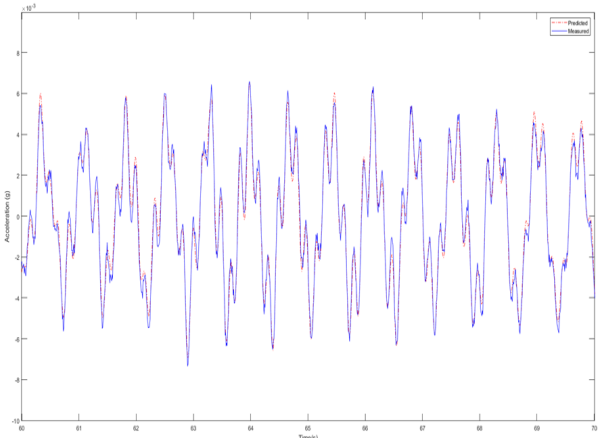

Figure 1. Comparison for the detailed view for the segment between 60s and 70s.

Acknowledgements

The support from National Natural Science Foundation of China (Grant No. 51808400), China, and Shanghai Sailing Program (Grant No. 18YF1424500), Shanghai, China is greatly acknowledged.

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NexGen燃烧器标准火焰冲击平板数值模拟研究

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摘要：新一代NexGen标准燃烧器是航空发动机防火试验的最主要条件，但实体防火试验属于破坏性试验，成本高、周期长、限制条件多。数值仿真防火试验是未来防火试验方法的重要发展方向。目前，国内外对航空发动机防火试验的仿真研究处于探索研究阶段。本文利用Fluent仿真软件研究了NexGen燃烧器标准火焰的特性，即标准火焰温度和热流的大小以及分布规律。为了研究NexGen燃烧器标准火焰多相流场与温度场，建立了涉及多相流、燃烧、传热过程的三维非预混燃烧数学模型，该模型与试验数据吻合良好。数值仿真防火试验结果表明:在测点处，标准火焰温度平均为1100℃，标准火焰热流密度平均为116KW/m^2；标准火焰在喷嘴出口水平法向平面上温度呈“3”型分布，且扩张锥壁面温度沿喷嘴方向逐渐升高；热流量测试平板向火侧热流密度高于背火侧，中间过火区域高于两侧未过火区域。

Effects of tree planting on the in-canyon air quality and thermal comfort

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Abstract: Due to increasing urbanization, more and more people are prone to heat stress in cities. One of the most efficient ways to reduce heat stress during periods of extensive heat is to increase tree planting (Chen et al., 2020). However, the wind speed reduction is a fairly disadvantage for urban trees due to their drag force, thereby worsening the outdoor air quality (Yang et al., 2020). Thus, it is essential to balance the tree planting' adverse effect (wind-blocking) and benefit (evaporative cooling and solar shading). The magnitude of these impacts is dependent on tree species because of their different physical and morphological configuration (leaf area density (LAD), canopy height, canopy spacing, and trunk height). Therefore, the present work focuses on the evaluation of such tree parameterizations that are developed and implemented within CFD by introducing additional source/sink terms into the transport equations to study the drag effects and cooling effects of the tree canopy, as seen in Figure 1. Based on the results of the thermal environment and pollutant dispersion, general suggestions are provided, which can constitute guidance and a reference for the future design of green spaces in residential districts.

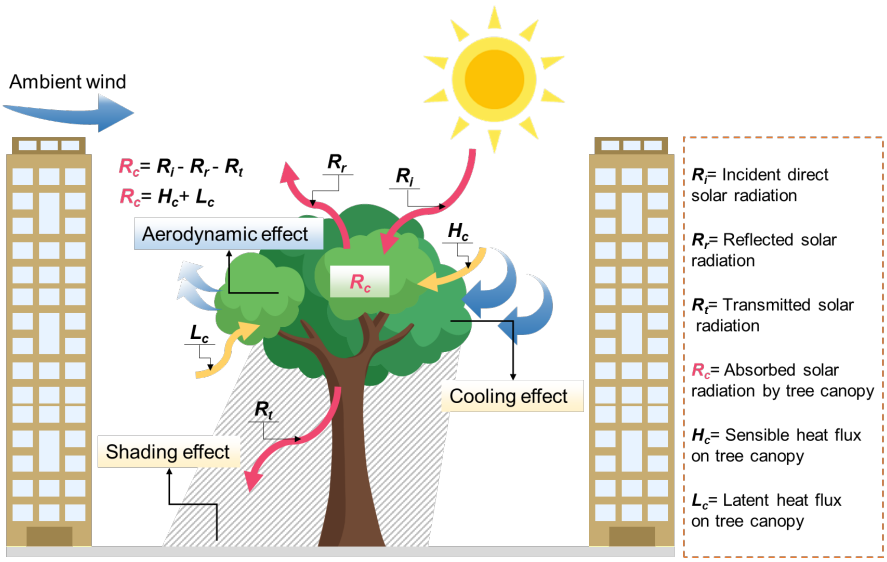

Figure 1. Schematic illustrating the aerodynamic effect, shading effect, and cooling effect of road-side trees within the street canyon

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Molecular dynamics simulation based squeeze strengthening effect analysis of magnetorheological fluids

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Abstract: Systematic molecular dynamics simulations are conducted on magnetorheological (MR) fluids under steady state, squeeze flows and shear flows. The present study concerns the squeeze-assisted MR fluid strengthening and correlates the suspensions' macroscopic rheological properties to their microstructure evolution in terms of the aggregation kinetics [1,2]. Simulation results demonstrate that the squeeze strengthening effect on the rheological properties of MR fluids is enhanced with the increasing magnetic field and becomes more prominent for dilute suspensions, but weakened with the increasing squeeze rate after the critical squeeze rate is surpassed. By microscopic inspection, it is found that the rheological properties of MR fluids under squeeze flows are consistent with the microstructured behaviors of MR suspensions in terms of the particle distribution, cluster kinetics, particle connectivity and magnetic energy. This study provides a microstructural insight into the squeeze-assisted MR fluid strengthening, which helps to attain an elegant design of MR devices with high shear performance requirements.

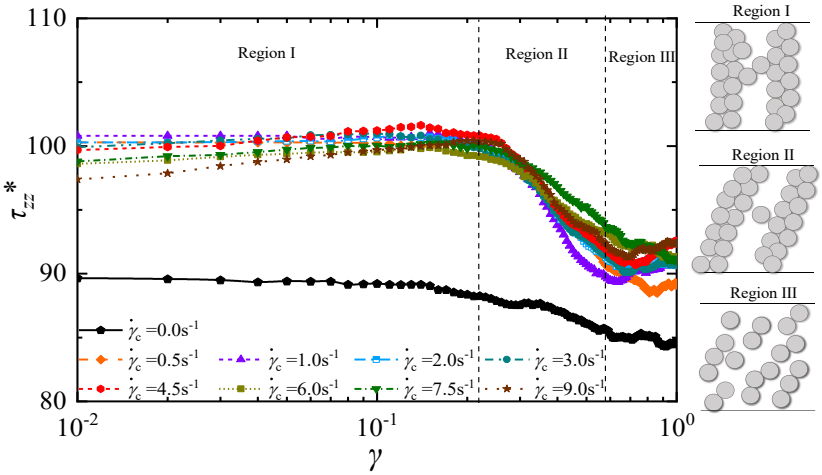

Figure 1. Normal stress of MR fluids at different squeeze rates as a function of shear strain

Acknowledgements

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A Model of Acupuncture Mechanical Effects

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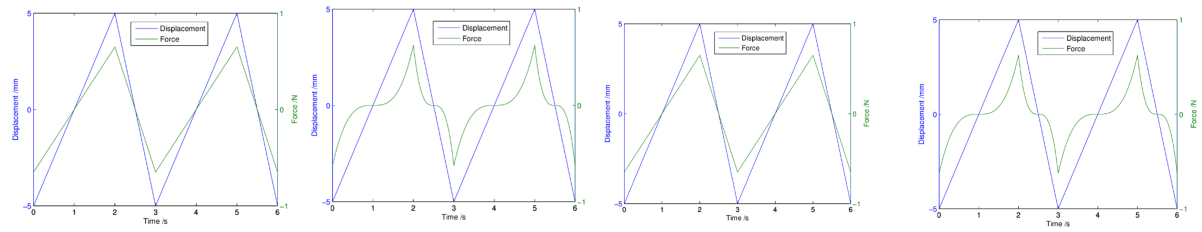
Abstract: Acupuncture, a physiotherapy, has been widely accepted all around the world. This study focuses on the influence of membrane structures, explains the acupuncture sensations from the aspect of mechanical properties. By mathematical modeling and numerical simulation, the scientific meaning of the acupuncture depth is investigated, phenomena and theory of acupuncture are discussed. The simulation results show that: (1) the fascial structure is the main contributor to the force on the needle, the axial force will gradually increase before pierceing the fascial, and suddenly decrease after pierceing the fascial; (2) there is an inverse relationship between the needle radius and the maximum radial stress, which indicates that the needle should not be too sharp to cause local stress concentration and piece the fascia layer; (3) the simulation results of comprehensively considering the static friction and sliding friction (Fig.1) is identical with the experiment results. This study proposes a preliminary study of mechanical effects of acupuncture manipulation, clarifies key factors affecting the stress on the needle, and explains the objective requirement of acupuncture depth to effective treatment.



(a) (b) (c)

(d)

Figure 1. The displacement and the force of the needle under non-slip boundary condition (a, $n(v,\Sigma)=1$, b, $n(v,\Sigma)=3$) and slip boundary condition (c, only including F_{fri}, d, including both F_{fri} and F_{ela}).

Acknowledgements

The authors wish to thank National Natural Science Foundation of China (81473750, 81574053 and 81590953) and Shanghai Key Laboratory of Acupuncture Mechanism and Acupoint Function (14DZ2260500)

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An adaptive network-based deep generative design method with applications to heat source layout design

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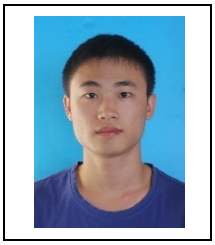

Abstract: Layout design problem deals with the placement of design components in a domain to achieve certain design objectives. Often these layout design problems involve a large number of design degrees of freedom and/or are subjected to various constraints, which makes the search for the optimal solution extremely challenging and slow when conventional design approaches are used. To overcome these challenges, an adaptive searching/learning strategy is proposed in this work and combined with neural network approach for layout design problems. The adaptive learning strategy can efficiently generate a sequence of design spaces iteratively. Each of these design spaces occupies a small portion of the entire design space, and hence only a small number of training data is required. Through an iterative learning and optimization process, the sequence converges to the portion that contains the optimal design, leading to an optimal design solution. To demonstrate the effectiveness of the proposed approach, heat source layout design problems as shown in Figure 1 were solved using the proposed method.

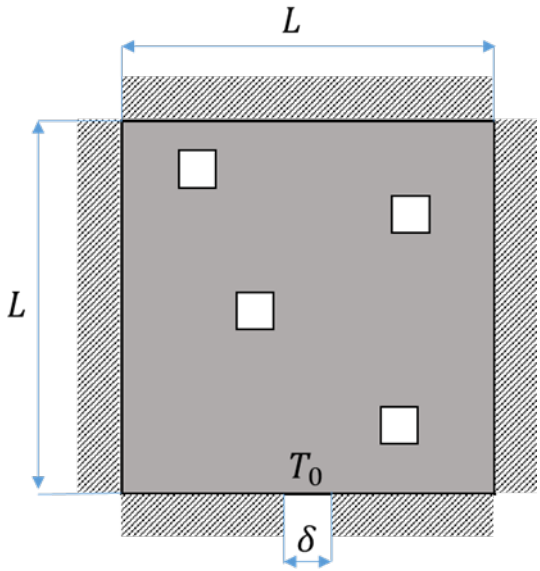

Figure 1. The heat source layout design problem in a square domain: The four squares in white denote four heat sources. The four sides of the design domain are adiabatic except the middle point of the bottom boundary, where the isothermal boundary with length δ keeps at a constant temperature T_0. The objective is to minimize the maximum temperature meanwhile satisfying certain constraints (if applicable).

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Molecular dynamics-based modelling of silica interface behavior

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Abstract: The steered molecular dynamics (SMD) method, developed based on Molecular Dynamics, was originally utilized in bio-molecules simulations (Izrailev et al., 1999). It has been widely applied to investigate the interface interactions at the atomic scale. A moving spring force to a group of atoms can be applied in SMD simulations. This study aims to investigate the interfacial friction behavior of silica using the atomistic approach. Silica slider and substrate are built from α-quartz and the Consistent Valence Forcefield (CVFF), which has been widely used in both organic and inorganic simulations, is adopted to describe the interactions (Kitson & Hagler, 1988). The SMD method is utilized to simulate the friction tests under constant velocity conditions. The interfacial friction simulations of silica under different normal forces, pulling velocities, and temperatures are conducted to explore the influence of environmental conditions. This study can provide new insight into the interfacial friction of the most widely used granular materials in civil engineering.

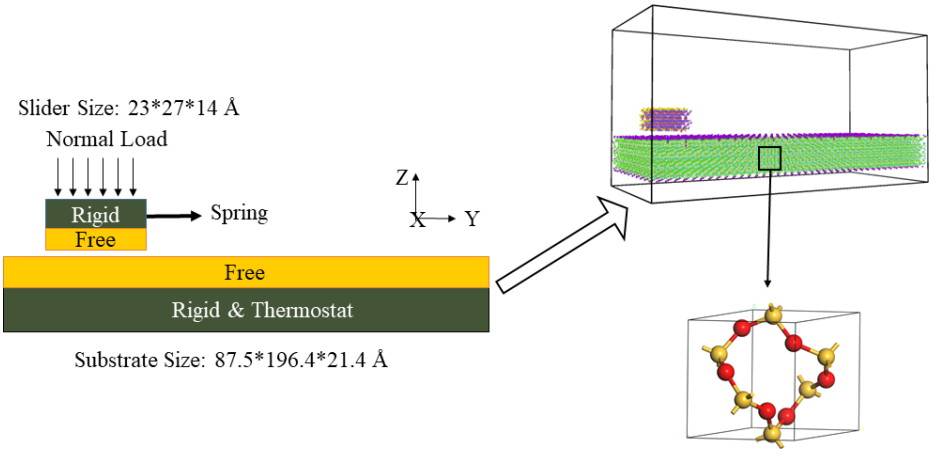

Figure 1. Schematic Diagram and Atomistic Model of Silica Interface

Acknowledgements

The authors wish to thank the financial support from Research Grants Council of Hong Kong (No. 15217220).

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Coupling effects in nanoscale electromechanical ion transport

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Abstract: At the macroscale, it was usually assumed that flows driven by different forces could be linearly superimposed. However, this assumption might no longer be valid at the nanoscale. Herein, we conduct MD simulations and investigate electromechanical transport of KCl solutions in graphene nanochannels. The variation of ionic currents shows a nonlinear coupling between pressure-driven and electroosmotic flows, which enhances the ionic currents for electromechanical flows compared with the linear superposition of pure pressure-driven and electroosmotic flows. The nonlinear coupling transport is attributed to the reduction of the potential energy barrier for K^+ and water molecules in the channel due to the density changes of K^+ and water molecules at the entrance of the channel.

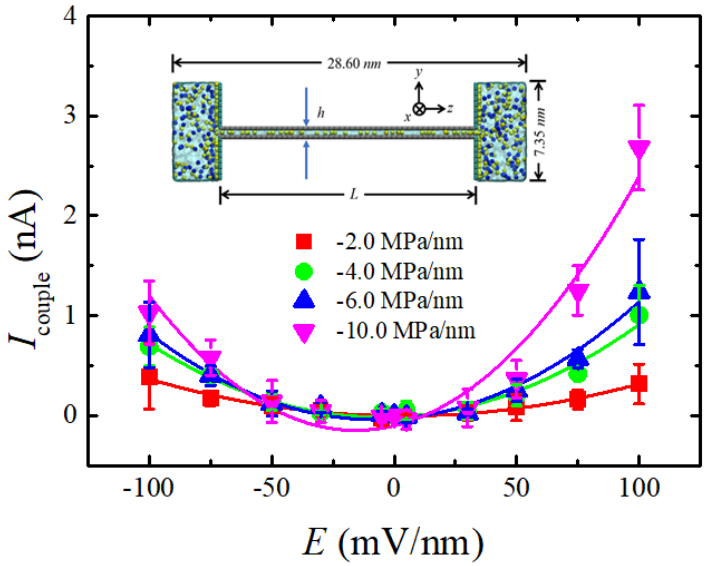

Figure 1. Current I_{couple} due to the coupling of pressure-driven and electroosmotic flows.

Acknowledgements

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Nanomechanical characterization of tungsten microwire

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Abstract: Tungsten is inherently brittle at room temperature that restricts its mechanical performance and reliability in structural and semiconductor applications at small scale. Here, we designed a tungsten microwire that introduces high-density dislocations but reduces grain boundary in tungsten via the combination of cold drawing and electron backscatter diffraction-guided microfabrication. The tungsten microwire shows large ductility with high strength. The plastic deformation at a high-stress level is through the motion of pre-existing high-density dislocations, crack-tip plasticity, and inhibition of grain boundary cracking as revealed by in situ electron microscopy tensile experiments. The results offer a practical approach to developing tungsten interconnect materials with superior mechanical properties and reliability.

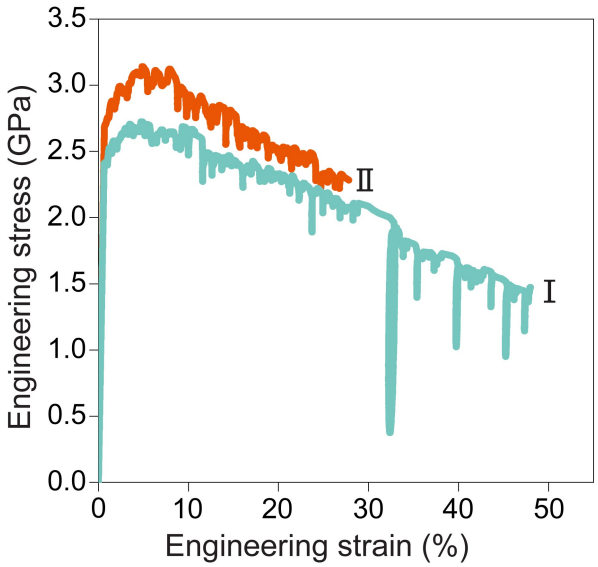

Figure 1. Engineering stress-strain curves of tungsten microwires I and II.

Acknowledgements

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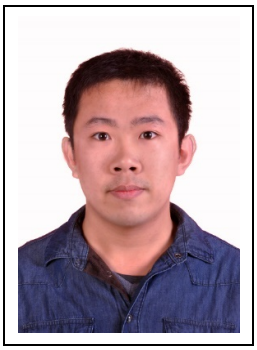
Size-dependent fracture behavior of GaN pillars under room temperature compression



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Abstract: Gallium nitride (GaN) offers high electron mobility, breakdown voltage and saturation velocity, which is an ideal candidate for advanced electronic and power devices. Meanwhile, they can be also used for microelectromechanical systems (MEMS) and micro/nano-mechanical devices. These applications fundamentally rely on their mechanical properties and structural reliability, in particular at the micro/nanoscales. In this paper, single crystalline [0001]-oriented GaN pillars with diameters ranging from ~200nm to ~1.5μm were microfabricated and systematically characterized by in situ compression tests inside SEM/TEM at room temperature. It is showed crack would nucleate at the top of the pillars with diameters >800nm and propagate axially during compression. However, pillars with diameters less than 700nm would deform plastically without splitting, with maximum stress up to 10GPa. The corresponding yield/fracture strengths show strong size effect, which increased from ~4GPa to ~11GPa with the diameter decreases from ~1.5μm to ~400nm. in situ TEM compression tests suggest that the formation of slip bands on the $(01\bar{1}1)$ plane dominates the plastic deformation of the pillars with ~200-700nm diameter, while both crack splitting and slipping bands shown in the pillars during the brittle-to-ductile transition diameter around 700 to 800nm. This work provides critical insights for developing robust GaN-based MEMS and power electronics applications.

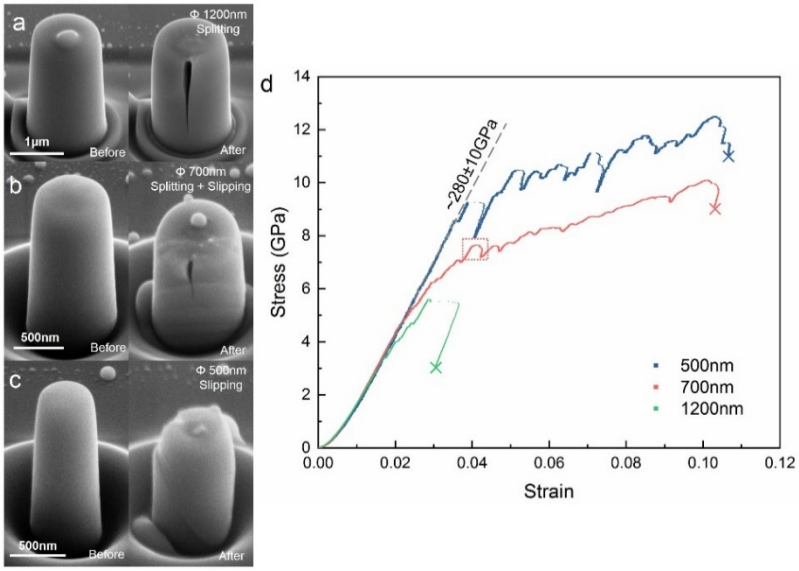

Figure 1. The morphologies of pillars with different diameters before and after compression and the corresponding stress-strain curves.

Acknowledgements

We acknowledge the financial supports from Hong Kong Research Grant Council (RGC) under the GRF CityU11207416, City University of Hong Kong under SRG 7005234, and National Natural Science Foundation of China under 11922215.

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Microalloyed medium-entropy alloy (MEA) composite nanolattices with ultrahigh toughness and cyclability

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Abstract: Three-dimensional nanolattices have recently emerged as an effective strategy to achieve high strength at low densities, by harnessing the combination of rationally designed topologies and nanoscale size effects[1]. However, most micro/nanolattices show an ineludible deterioration of mechanical properties upon repeated loading due to localized brittle fracture[2,3]. Here, by the development and deposition of $CoCrNiTi_{0.1}$ microalloyed medium-entropy alloy (MEA) with extra low stacking fault energy, we fabricated ultratough MEA-coated nanolattices that can exhibit unprecedented surface wrinkling under compression. Particularly, nanolattices with alloy film thickness ~30 nm can repeatedly withstand strains exceeding 50% with negligible strut fracture, while the elastic polymer core promotes recoverability and structural integrity. Furthermore, our MEA composite nanolattices possess high energy absorption (up to 60 MJ m^{-3}) and specific strength (up to 0.1 MPa kg^{-1} m^3), providing a robust platform for a plethora of micro/nano-mechanical and functional applications.

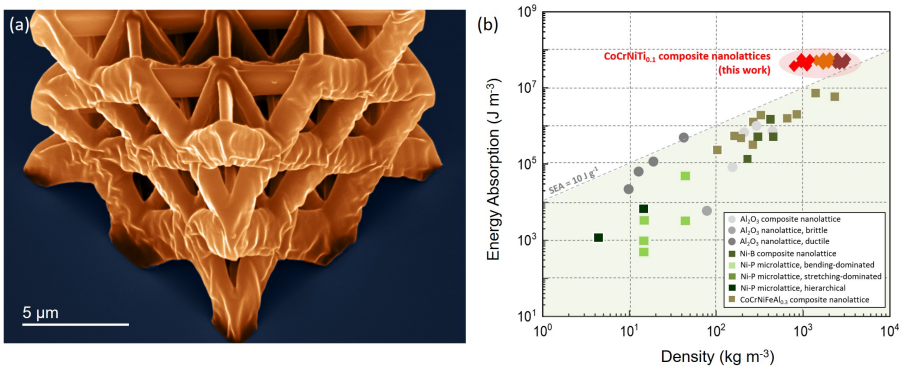

Figure 1. (a) Wrinkled MEA composite nanolattice obtained after uniaxial compression. (b) Comparison of the energy absorption capabilities of MEA composite nanolattices with previously reported micro/nanolattices.

Acknowledgements

The authors gratefully thank the funding support of Shenzhen Science and Technology Innovation Committee under the grant JCYJ20170413141157573. Part of this project was supported by City University of Hong Kong (Project Nos. 9610461, 9680108, and 9610425) and the National Natural Science Foundation of China (NSFC) Project 11922215.

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2. Gao, L., *et al.*, *Advanced Engineering Materials* (2018) **20** (1), 1700625
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基于有限元方法的轴向及横向载荷共同作用下的石墨烯变形研究

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Abstract: 从第一性原理计算石墨烯中碳原子间的相互作用通常需要很大的计算成本，尤其是对于尺寸相对较大的样本。基于以下假设建立石墨烯的有限元模型。将石墨烯视为空间框架结构，碳原子之间的共价键视为承载构件，而将碳原子视为构件的节点。具体而言，根据石墨烯中碳原子位置建立节点，最邻近碳原子之间通过三维弹性梁单元连接，以模拟原子间相互作用关系。其参数由分子力学与连续体力学之间的关系转换确定。根据创建的有限元模型，研究在轴向载荷和横向载荷同时作用下手性、模型尺寸对石墨烯变形情况的影响，并与基于经典力学得到的计算结果进行对比。

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Effect of surface topography on anisotropic friction of graphene layers

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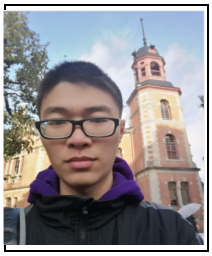

Abstract: Tribological behavior of graphene layers has been a focus of intensive research interest since its crystal lattice structure can be exploited to achieve incommensurate contact, leading to nearly zero friction, namely structural superlubricity. However, wrinkling undulations are omnipresent on graphene and difficult to be completely eliminated, which inevitably resists superlubricity in reality. Here, we explore how the presence of surface wrinkles affects nanotribological behavior of graphene sliding systems. Using a dimensionless parameter based on the topographic geometry, we propose a set of quantitative criteria permitting incommensurate-induced low friction even superlubricity to retain, despite the presence of surface wrinkles. Failing the criteria, achievement of superlubricity on wrinkled surface becomes implausible with unfavorable anisotropy and considerable friction. Besides, we examine the influence of diverse spatial topographic patterns such as stripe, checkerboard and herringbone on tribological behavior, and reveal that surface wrinkles can precisely tune the oscillating undulation of friction response. The proposed criteria may serve as an indicative reference that allows predicting the state of friction on practical, wrinkled graphene, and eventually assist the design of nanotribological systems with tunable friction.

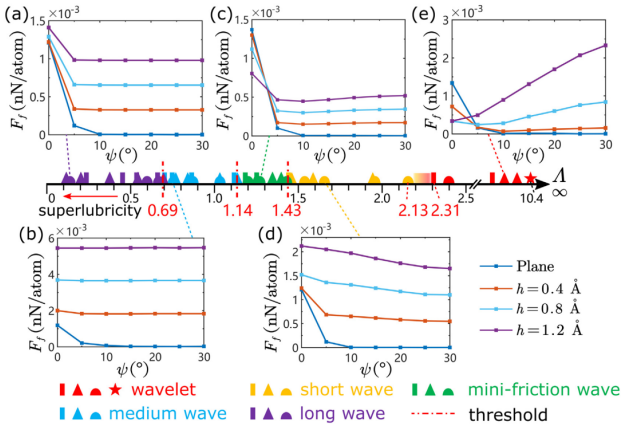

Figure 1. Phase diagram of nanotribology characterized by the dimensionless parameter Λ for different flakes and wrinkled substrates.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (Grants No. 11872150 and 11890673), Shanghai Rising-Star Program, China (Grant No. 19QA1400500) and Shanghai Chenguang Program, China (Grant No. 16CG01).

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A LSTM Surrogate Modelling Approach for Caisson Foundations

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Abstract: This study proposes a hybrid surrogate modelling approach with the integration of deep learning algorithm long short-term memory (LSTM) to identify the mechanical responses of caisson foundations in marine soils. The LSTM based surrogate model is first trained based on limited results generated from the SPH-SIMSAND based numerical simulations with a strong validation, thereafter it is applied to predict the mechanical responses of soil-structure interaction and the failure envelope of unknown caisson foundations with various specifications as testing. The results indicate that the LSTM based model is more flexible than macro-element method, because it can directly learn the failure mechanism of caisson foundation from the raw data, meanwhile guarantees a high computational efficiency and accuracy in comparison with physical and numerical modelling. LSTM based surrogated model shows a great potential of application in engineering practice.

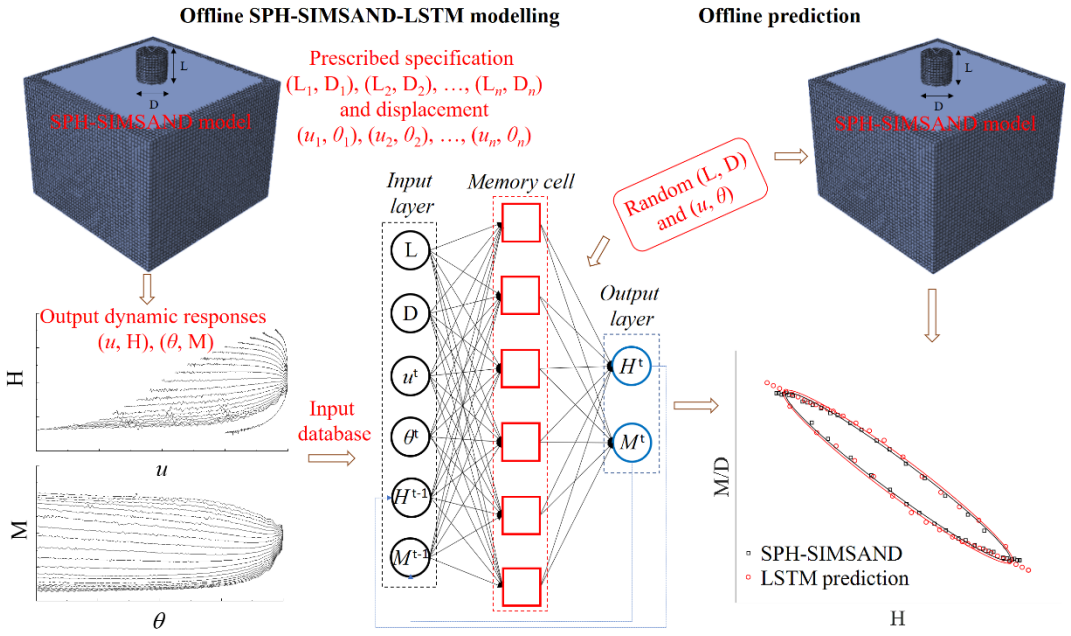

Figure 1. Schematic view of hybrid SPH-SIMSAND and LSTM surrogate modelling process

Acknowledgements

This research was financially supported by the Research Grants Council (RGC) of Hong Kong (Grant No: R5037-18F) and the Key Special Project for Introduced Talents Team of Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou) (No: GML2019ZD0503.

Investigation of particle size effect of granular materials through DEM

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Abstract: To explore the particle size effect of sand, a series of triaxial tests are simulated with a Discrete Element Method (DEM) model (Fig.1). The membrane in the triaxial test is simulated by a network of bonded spherical balls in DEM. DEM simulations of triaxial tests with different sizes are carried out on both the uncrushable and crushable specimens with a constant confining pressure. The result shows that the shear strength of the specimen with large particles is greater than that of the one with small particles. In addition, the shear dilation becomes more obvious with the increasing of the particle size. In the tests considering particle breakage, the shear strength difference between small-particle samples and large particles decrease with the increase of the crushability degree of sand particles.

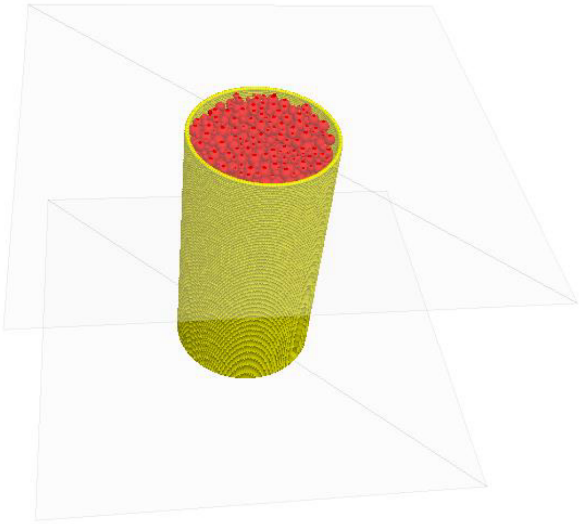

Figure 1. Numerical sample in the DEM simulation.

Acknowledgements

The authors would like to thank the GRF grant (No. 15209119) of Research Grants Council of Hong Kong for the financial support.

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Simulating propagation of complex cracks in rocky masses by numerical manifold method

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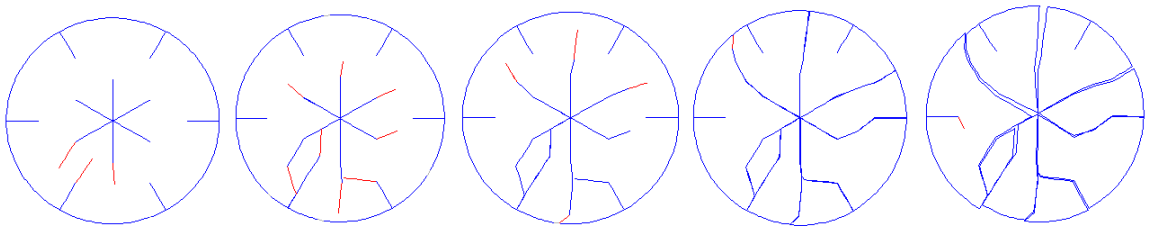
Abstract: The numerical manifold method (NMM) characterized by the unique dual-cover system (i.e. mathematical cover and physical cover) provides a unified framework for modeling the progressive failure process usually occurred in rocky masses. In the NMM, the mathematical cover determines the approximation format of the numerical solution, while the physical cover relies on the considered problem domain. This means that the interpolation space and the integral domain are defined independently in the NMM, which renders that the meshes are not necessary to match with the boundaries/discontinuities of the problem domain. Just because of this, the NMM has the prominent flexibility and convenience to capture the complex crack evolution phenomena (e.g. initiation, propagation, coalescence, and etc.) in jointed rocky masses. In the current study, some preliminary investigations are presented. More in-depth theoretical and applied researches are under way.



(a) Step 37 (b) Step 39 (c) Step 40 (d) Step 43 (e) Step 92

Figure 1. Crack evolution in jointed rocky disk from steps 37 to 92.

Acknowledgements

The study is supported by Hong Kong Research Grants Council grant Nos. 16214519 and N_HKUST621/18.

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A coupled model for simulating desiccation-induced soil cracking

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Abstract: Based on the combined finite-discrete element method (FDEM), this paper presents a moisture diffusion-stress-fracture coupling model to simulate desiccation-induced cracking in soils. The model mainly contains three parts. The first part is the moisture diffusion model, the second part is the influence of crack propagation on moisture diffusion, and the third part is the coupling of moisture diffusion and mechanical fracture. The model is used to study the soil desiccation cracking and the evolution pattern of the crack is good agreement with the experimental results. Besides, several main factors affecting soil desiccation cracking are also discussed, including the initial elastic modulus, the moisture shrinkage coefficient, and the soil thickness. The moisture-diffusion-stress-fracture coupling model provides a new research tool for studying the mechanical mechanism of soil desiccation cracking.

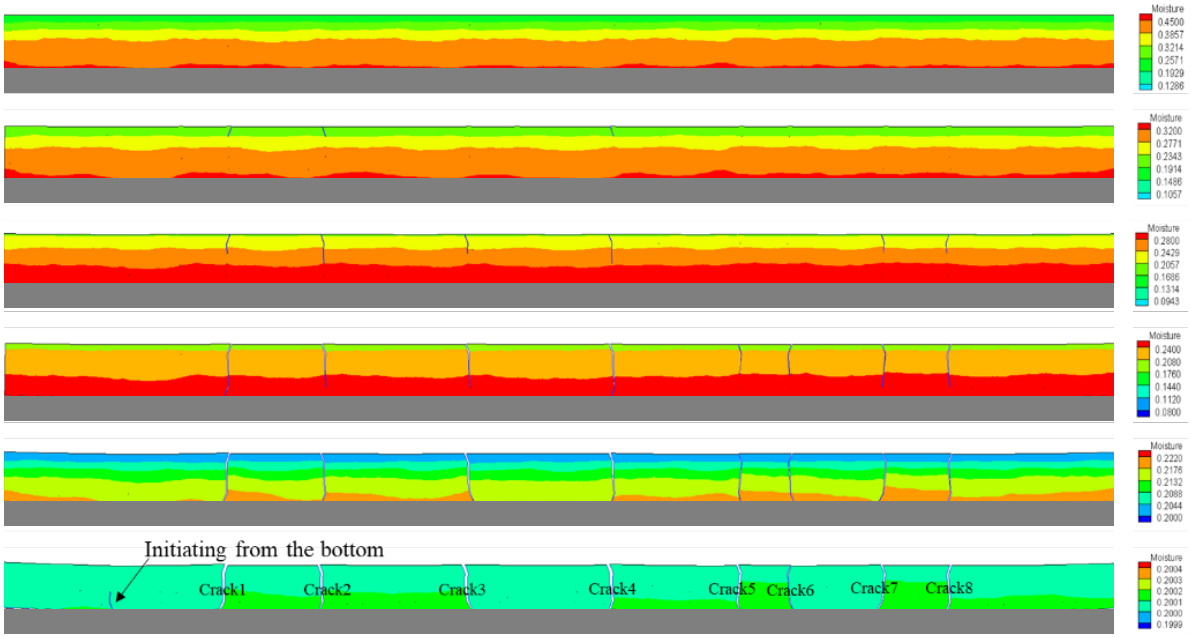

Figure 1. Crack initiation and propagation in desiccated soil

Acknowledgements

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Influence of dip angle on 1-D creep behaviour of natural clays

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Abstract: The time-dependent mechanical behaviour is a key issue for sustainable engineering design and geotechnical analysis in clay deposited regions around the world. To study the fundamental viscous characteristics of clays and provide a solid theoretical support for engineering practice and research on clays, this study focuses on experimentally investigating the influence of dip angle on 1D creep behaviour of natural clays. Soft Hong Kong marine clay and stiff Boom Clay are selected for the study.

For each clay, specimens prepared for oedometer tests are cut from the soil block at several different angles, e.g. at angle θ of 0° (i.e., perpendicular to the deposition plane), 30°, 60°, and 90° (i.e., parallel to the deposition plane). Using these specimens, a series of oedometer tests on both clays are conducted in the laboratory.

Small specimens will be cut from samples of different stages of creep for the purpose of investigating microstructural evolution. The region of interest for observation is the surface of the vertical plane. Microstructure analysis (e.g. SEM) is also carried out for the microstructural evolution of clays during creep.

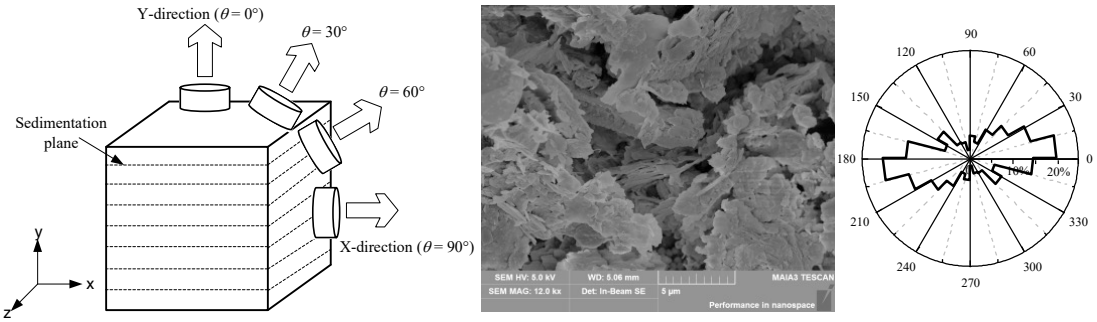

Figure 1. A sample of a figure

Acknowledgements

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Peridynamics simulation of cemented granular materials using developed micro-mechanical models

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Abstract: Cemented granular materials (CGMs) are often used in engineering construction. Advanced numerical modelling provides an effective way to understand the mechanical behaviour and failure mechanism of CGMs. Peridynamics is a continuum-based non-local mesh-free method which is suitable for initiation and propagation of fractures in continuum media. The integral based equation of motion in Peridynamics instead of classic partial differential equations prevents singularities in calculations close to the fracture surfaces and makes Peridynamics a powerful tool to simulate fractures and cracks. However, Peridynamics demands high computational cost in large-scale problems and has been never used in simulating CGMs. In this research, Peridynamics has been developed to simulate mechanical behaviour and failure of CGMs in large-scale dimensions by incorporating newly developed micro-mechanical material and contact models. The interactions between complex grain geometries have been also considered.

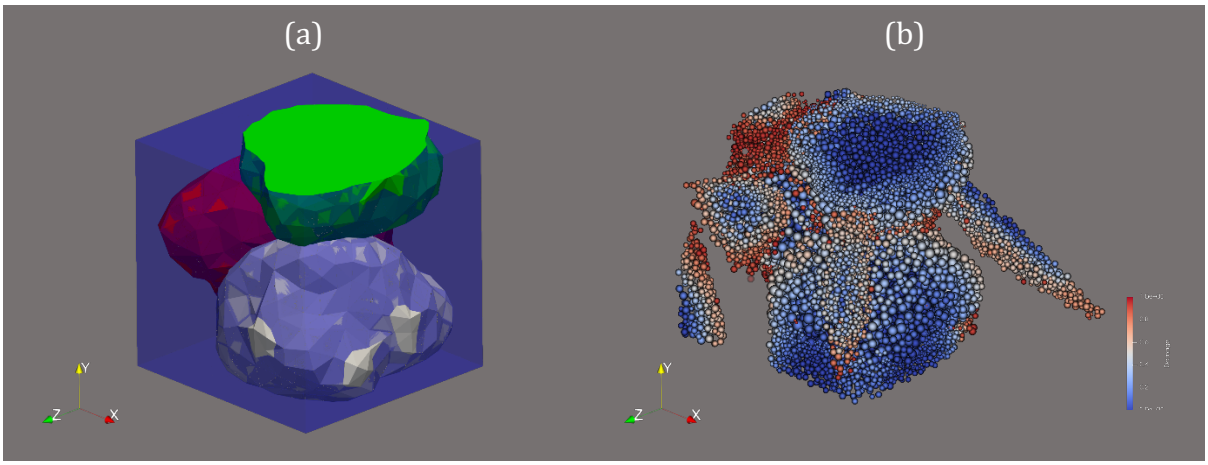

Figure 1. (a) geometrical scheme of rock particles in a cubic cement matrix, (b) Peridynamics simulation of the cemented particles failure.

Acknowledgements

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The Performance of a Flexible Flat-Bladed Wind Turbine: Numerical Approach

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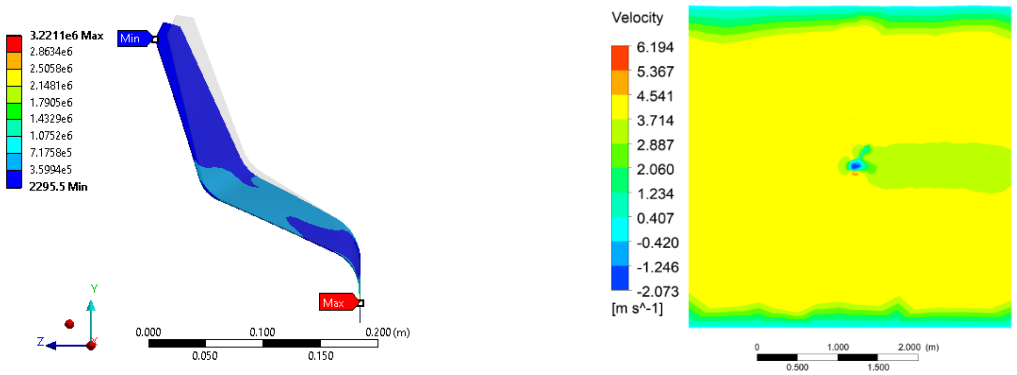
Abstract: Flexible blades wind turbines are getting more attention nowadays because of its benefit in reducing blade loads and improving aerodynamic performance. A new passive flexible flat-bladed wind turbine inspired by the Borneo Camphor seed is proposed. In order to understand the phenomena caused by the flexible flat-bladed wind turbine design, the numerical simulation method was used. This study was conducted by using the fluid structure interaction (FSI) to predict the power performance of the 700 mm diameter flexible flat-bladed wind turbine. The performance of the inspired flexible flat-bladed wind turbine was compared with a flat plate rigid blades wind turbine. The FSI software is a strong coupling of the ANSYS Fluent and ANSYS Mechanical APDL that allows the modelling of aeroelastic properties of the wind turbine. These integrated models allow the prediction of the performance of the inspired flexible flat-bladed wind turbine. The predicted results showed that given the same solidity of the blades, the inspired wind turbine exhibits higher starting torque, higher power coefficient and faster rotational speed. The current study demonstrated the potential of the flexible flat-bladed wind turbine in reducing the cost of wind power while being competitive in terms of performance.



(a) (b)

Figure 1. (a) Von-Mises stress in Pa contour plot of blade and (b) wake velocity contour plots at longitudinal cross-section of wind turbine model.

Acknowledgements

The work described in this paper was fully supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China [Project No. 9042509 (CityU 11210517)].

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Fatigue Analysis of a Floating Offshore Wind Turbine Subjected to Joint Wind and Wave Loads

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Abstract: Floating offshore wind turbines (FOWTs) are increasingly being studied and deployed to harvest high-quality wind energy in deep sea. Due to the large-amplitude rigid motion of the floating platform, the FOWT towers experience more severe vibration and fatigue damage compared to the bottom-fixed offshore wind turbines. In the present study, the fatigue damage and fatigue life of a spar-type FOWT tower are assessed numerically. To this end, the stochastic dynamic response and reliability analysis model of floating offshore wind turbines (StoDRAFOWT model) is firstly established by integrating the multibody dynamics and the finite element method. In this model, the geometric nonlinearity and rotational stiffening effects of blades, the pitch control and torque control mechanisms and the coupling between the blades, tower, platform and the mooring system are all taken into consideration (Song et al. 2020). The StoDRAFOWT model is benchmarked against the state-of-the-art wind turbine analysis code FAST through numerical simulations under different load conditions. Then, the fatigue life of a spar-type FOWT tower is evaluated on the basis of the StoDRAFOWT model. In the fatigue analysis, the long term joint probability distribution of wind and wave environmental variables is constructed by the C-vine copula model based on the reanalysis data in the South China Sea. The wavenumber-frequency joint spectrum and the rotational sampling method proposed by Chen et al. (2020) are adopted in the simulation of wind speed field of wind turbines (Chen et al. 2018; Song et al. 2018, 2019). Finally, the fatigue damage and fatigue life of the FOWT tower are evaluated by adopting the S-N curve of steel material and Miner's fatigue rule.

Acknowledgements

Financial supports from the National Natural Science Foundation of China (Grant Nos. 11672209, 51725804 and 51878505) and the Committee of Science and Technology of Shanghai China (Grant No. 18160712800) are highly appreciated.

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Unsteady Aerodynamics of Floating Wind Turbine: an Experimental Study

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Abstract: The Floating Wind Turbine (FWT) is regarded as one of the most promising alternatives for next-generation offshore wind energy exploiting systems. Under the complex environmental excitations, the FWT floater usually experiences excessive 6-DOF (degree of freedom) motions, which significantly impacts the FWT aerodynamics. This paper investigates the unsteady aerodynamics under the floater oscillations with extensive experimental tests. A dedicated experimental apparatus is developed, and systematical model tests are carried out at State Key Laboratory of Ocean Engineering (SKLOE) at Shanghai Jiao Tong University. Results showed that the floater surge and pitch motions dominate the influences on FWT aerodynamic performance. The power production is altered by the floater motions. Also, the floater oscillations significantly amplify the dynamic loads of the FWT, increasing the fatigue damages and threating the system safety.

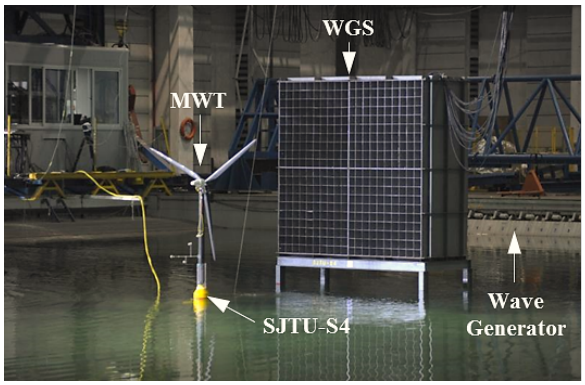

Figure 1. Experimental apparatus in the wave basin of SKLOE at SJTU.

Acknowledgements

The authors wish to thank the financial support from National Natural Science Foundation of China (Grant No.11632011) and Natural Science Foundation of Shanghai (Grant no.19ZR1426300).

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燃料电池低温快速启动中冰及构件的非傅里叶热传导和热应力分析

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摘要：燃料电池因其效率高、污染物排放少在汽车等领域得到广泛应用，但低温快速启动技术的瓶颈限制了其大规模商业化的发展。当燃料电池低温启动时间达到秒级，温度发生急剧变化，使燃料电池内冰及构件在较短时间内产生大量的热交换，从而产生冲击热应力。此外，由于冰通常非均匀地分布于膜电极组件（MEA）、气体扩散层、流道及密封胶表面或内部，因此需要考虑复连通域热冲击问题。本文建立了一个冰与构件受瞬时传热情况下的分析模型，基于热冲击条件，热流矢量传播与温度梯度之间存在时间延迟，本文采用非傅里叶热传导方程来描述该问题，得到了材料内部温度分布的表达式，并将所得解与传统傅里叶热传导方程的解进行比较。同时，通过已经求得的温度场，求得了应力场，给出了热应力随空间的变化。

致谢

感谢国家重点研发计划“燃料电池动力系统多目标优化能量管理”(2018YFB0105501)的资助。

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FLVIS: A Novel Pose Estimation Approach for Aerial Robots

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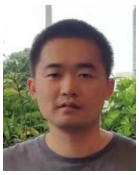

Abstract: A stereo visual-inertial system fuses the information from a stereo camera and an IMU to estimate the pose. Most of the current works are based on either a filter-based framework or an optimization-based framework. Both frameworks focus on finding the most appropriate prediction to satisfy every single measurement. As the amount of input data increases, more computational power is required. For payload sensitive aerial robots, there is a conflict between the limited computational resources and the real-time processing requirement. We present a novel stereo visual-inertial pose estimation framework. In this framework, the pose estimation process is modeled as a control system. Designed feedback or feedforward loops are introduced to achieve the system's stable control, which includes a gradient decreased feedback loop, a roll-pitch feedforward loop, and a bias estimation feedback loop. This system, named FLVIS (Feedforward-feedback Loop-based Visual Inertial System) [1], is evaluated on the popular EuRoC MAV dataset. FLVIS achieves high accuracy and robustness with respect to other state-of-the-art visual SLAM approaches. The system has also been implemented and tested on a UAV platform. The source code is public to the research community [2].

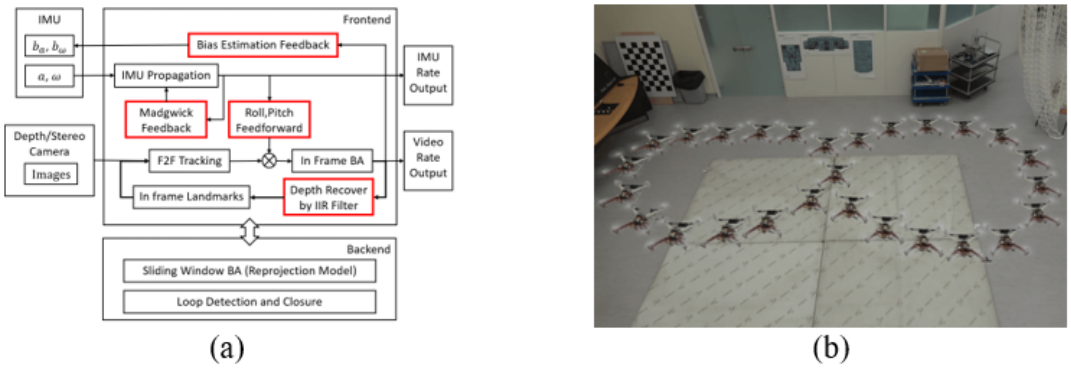

Figure 1. System overview and the UAV test. (a) Simplified system workflow, (b) UAV test (composite image).

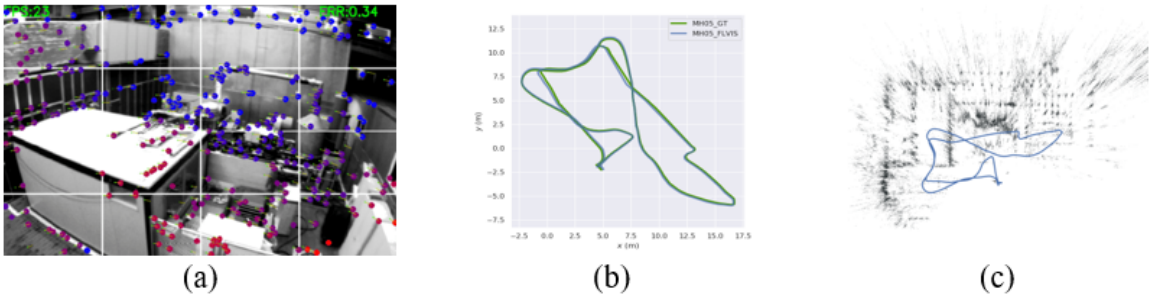

Figure 2. Test on EuRoC dataset. (a)image view, (b)estimate pose and ground truth, (c)sparce point cloud map.

Acknowledgements

This research is supported by EMSD HongKong under Grant. DTD/M&V/W0084/S0016/0523.

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[2]https://github.com/HKPolyU-UAV/FLVIS

Active Phononic Crystal Beam on Elastic Foundation for Topologically Protected Flexural Wave Propagation

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Abstract:

Actively controllable engineering structures are of great research interest in these several decades. In this regard, phononic crystals or metamaterials by active control have been one of the most promising candidates due to the unique behaviours in real applications. This work presents the actively controllable frequency response of the topologically protected interface modes (TPIM) in a phononic crystal beam-foundation system. The TPIM enables robust wave transportation in the interface between two substructures and it is immune to backscattering of any defects of disorders. With the employment of the negative capacitances, the system substructure is designed as an A-B-A phononic crystal beam. Then, the plane wave expansion (PWE) method and finite element simulation are utilized to obtain theoretical and numerical results, respectively. The topologically protected phase transition in a substructure and the TPIM in the whole system can be captured by tuning negative capacitances. However, due to the shortcomings of negative capacitances, this study capitalizes the effects of elastic foundation/supports to improve the active control of the wave propagation. High efficiency of foundation stiffness on system tuning is examined. A wider working frequency range of the TPIM is allowed in this controllable system.

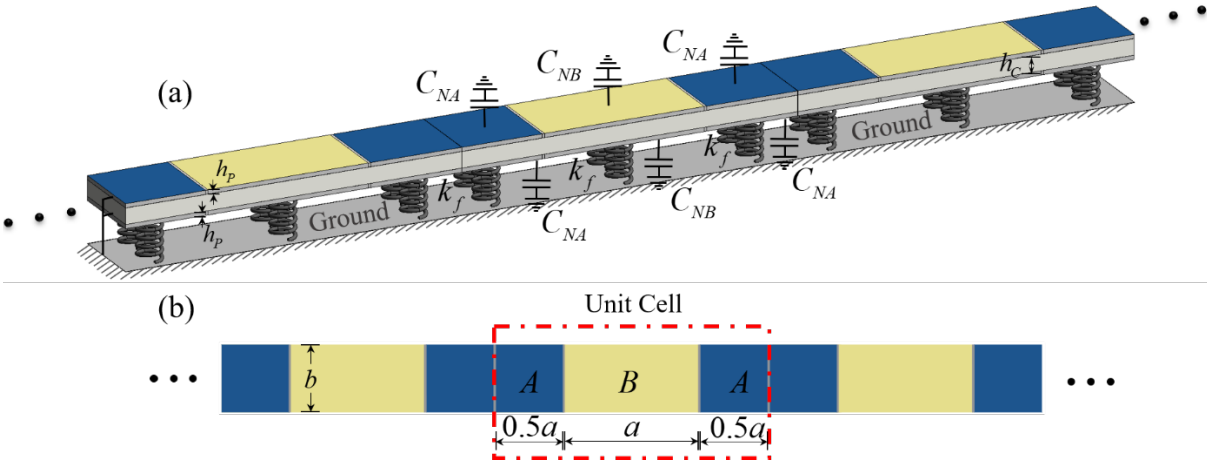

Figure 1. A phononic crystal composite beam connected with negative capacitances resting on an elastic foundation: (a) three dimensional view; (b) top view of the system.

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The authors wish to thank Dr. Weijian Zhou for his help in modelling and computational work in this study. The work described in this paper was supported by General Research Grants from the Research Grants Council of the Hong Kong Special Administrative Region (Project No. CityU 11216318).

Size-dependent mechanical properties of low-stacking fault energy multi-component alloys at small scales

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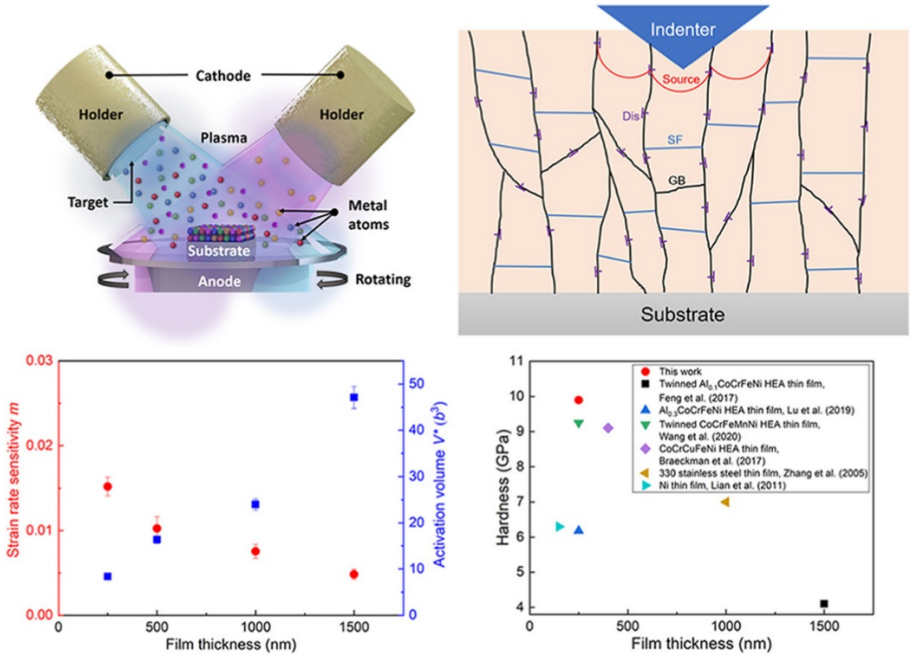
Abstract: Multi-component alloys (MCAs) exhibit excellent and tunable mechanical properties, making it an attractive candidate for various engineering applications. In this work, the size-dependent microstructure and mechanical behaviors, including the hardness, strain rate sensitivity, and activation volume of stacking faulted $Al_{0.1}$CoCrFeNi MCA thin films were systematically investigated. The recrystallized and pre-deformed CoCrNi MCA, introduced with high-density deformation twins, exhibits an unprecedented high yield strength up to 2.1 GPa. We found that the highly distorted deformation twins provide strong resistance to crack propagation and the activated dislocation motion accommodates further plastic deformation. The findings provide insights into understanding the size-dependent mechanical behavior of MCAs with low-stacking fault energy and offer some clues to achieve their optimized mechanical performance at small scales.



Acknowledgements

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The Role of Shear in Ice Crystallization

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Abstract: Ice crystallization in shear flows is a common phenomenon in nature. It is of great importance in various areas, such as atmospheric science, geology, and transport. Ice crystallization consists of two major processes, i.e., ice nucleation and ice growth. Nucleation is the starting point of crystallization during which water molecules in a supercooled state start to gather into ice clusters. Small ice clusters form and disappear during the nucleation process. The continuous growth of ice is triggered when ice clusters of critical size are formed. The kinetics of ice nucleation and growth depend on the thermodynamic and dynamic properties of water, which are affected by the shear flow. By using molecular dynamic simulations, we investigated the influence of shear rate on the nucleation rate and growth rate of ice. We found that both the nucleation rate and growth rate change nonlinearly with increasing shear rates and reach maxima at intermediate shear rates [1, 2]. For ice nucleation, the nonlinear variation of the nucleation rate with shear rate is caused by two distinct effects. First, shear increases the free energy barrier, hindering the nucleation of ice. Second, shear enhances the mobility of water molecules, promoting the formation of ice crystals. These two effects compete, leading to a maximum nucleation rate at an intermediate shear rate. For ice growth, the ice growth rate is mainly determined by the dynamics of the hydrogen bond network. On the one hand, shear can break the hydrogen bond in liquid, which causes the reorganization of water molecules at the liquid-ice interface, leading to the formation of ice. On the other hand, shear destabilizes the water-ice hydrogen bond, hindering the growth of ice. At low shear rates, the ice growth rate increases with the shear rate because the former effect is important. At higher shear rates, the latter effect becomes dominant and the growth rate decreases with the shear rate. The results of this work provide useful information about the formation of ice under shear and offer insights into regulating ice crystallization through water flow.

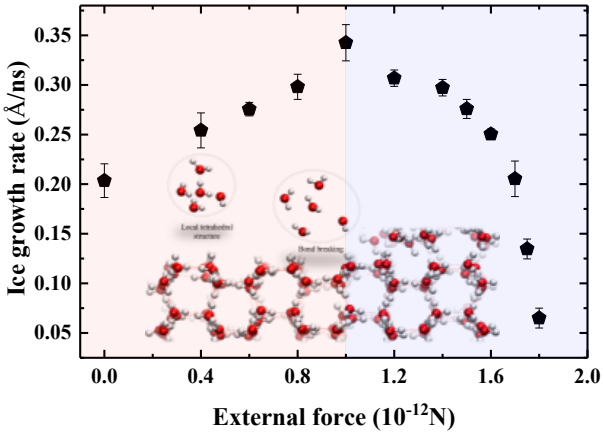

Figure 1. Ice growth rate as a function of the external force which is used to generate a shear flow. The inset shows the ice growth process.

Acknowledgements

This work was supported by the Research Grants Council of the Hong Kong Special Administrative Region under grant no.16228216 and the National Natural Science Foundation of China under grant no. 51776007.

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Pattern formation in core-shell spheres

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Abstract: Curvature-induced symmetry-breaking pattern formation and transition are widely observed in curved film-substrate systems across different length scales. Here, we find, both experimentally and theoretically, that morphological pattern selection of core-shell spheres, upon shrinkage of core or expansion of surface layer, is primarily determined by a single dimensionless parameter C_s which characterizes the stiffness ratio of core-shell and geometric curvature of the system. Various surface morphology, including local dimples, buckyball, labyrinth and checkerboard patterns, could be observed in the post-buckling stage for the core-shell spheres with different C_s. Pattern selection based on this single key factor remarkably agrees with our experimental observations on oxidized PDMS microspheres in the entire validity range. Furthermore, utilizing liquid crystal polymer (LCP), tunable sophisticated wrinkling patterns in LCP shell-core spheres can be implemented via controlling the orientation of director in LCP shells. Our results not only provide fundamental understanding of pattern selection in spherical film-substrate systems, but also pave a promising way to facilitate the design of morphology-related functional surfaces.

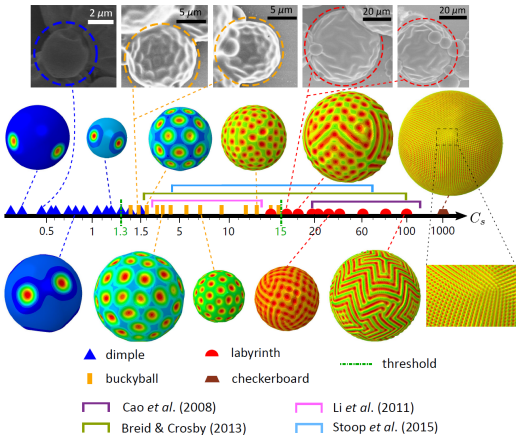

Figure 1. Computed phase diagram of core-shell spheres, with representative experimental wrinkling modes.

Acknowledgements

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Research on characteristics of solidified clay produced by flocculant-dredged slurry based on bender element test

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Abstract: Due to the shortage of river sand and rising prices, Macau's reclamation is facing difficulties. Our research group proposes to recycle the waste dredged slurry and add flocculants to solve the problem of slow drainage and consolidation of soft foundations after slurry reclamation. Bender element is a relatively new and mature non-destructive testing technology used in geotechnical engineering. The bender element sensor made of piezoelectric ceramic material can be used to quickly and accurately measure the shear wave velocity and shear modulus of the soil, which can help verify the feasibility of the new method we proposed in reclamation engineering. I will introduce the currently produced bender elements test based on the background of the new method and some problems encountered in the testing process, discusses some results of data analysis and soil performance produced by new method.

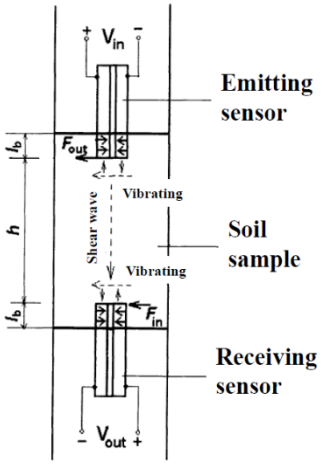

Figure 1. The testing principle of bender element.

Acknowledgements

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Study on Fast Cold Start-Up Method of Proton Exchange Membrane Fuel Cell Based on Different Heating Technology

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Abstract: The rapid cold start of the polymer electrolyte membrane fuel cell (PEMFC) at low temperatures is a crucial factor to guarantee fuel cells' operation under severe weather conditions and prolong their lifetime. In order to realize the rapid cold start of the proton exchange membrane fuel cell stack at low temperature, the present paper established a 20-layer fuel cell stacks and an ice layer above the flow channel. To study the melting process and melting time of ice, electric heating method and hot air purging method are utilized to heat the fuel cell stack. The fluid simulation software Fluent is used to simulate and analyze the ice melting process and melting time based on the solidification melting model and the multiphase flow model. The results show that the electric heating method and the hot air purging method can both achieve the goal of rapid cold start. At the end of the article, different flow channel structures are designed to study the cold start performance. The results show that in the case of electric heating, the design of the flow channel has only little effect on the cold start performance of the PEMFC stack and in the case of hot air purging, the design of the flow channel has a greater impact on the cold start performance of the PEMFC stack.

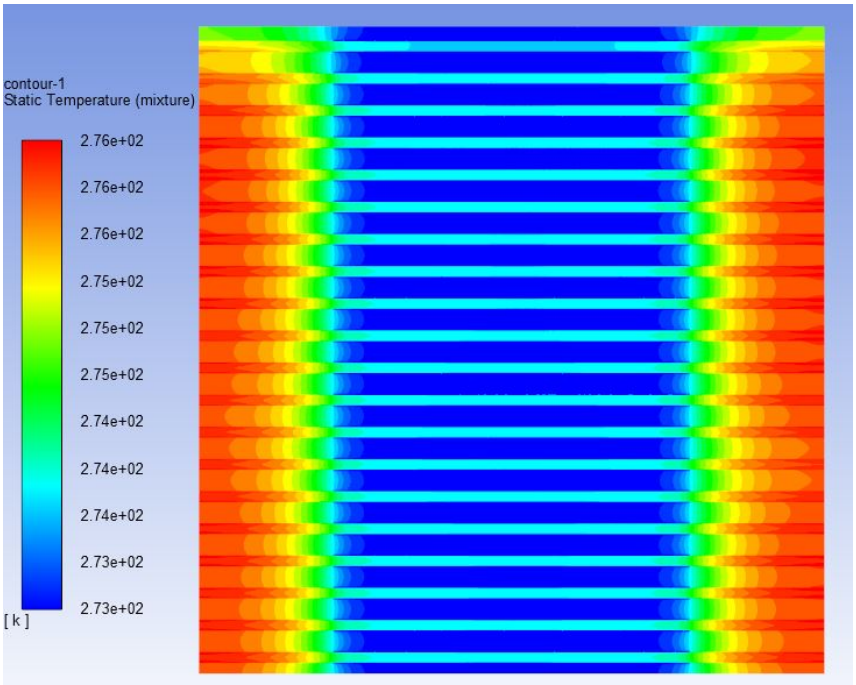

Figure 1. Temperature contours of the PEMFC.

A finite strain model predicts oblique wrinkles in stretched anisotropic film

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Abstract: Transverse wrinkles commonly occur in a uniaxially tensile elastic membrane and can vanish upon excess stretching. The wrinkling direction is usually perpendicular to the stretching direction under isotropic elasticity. Here, we show that wrinkles are orientable by material anisotropy, such as in fiber-reinforced or fibrous films, and the wrinkling orientation can be tuned by varying the stiffness and direction of fibers. To quantitatively describe large anisotropic deformations and predict morphological evolution, we develop a finite strain model by introducing anisotropic, hyperelastic constitutive law into the geometrically extended Föppl-von Kármán nonlinear plate theory. We find that the shear modulus ratio between fibers and matrix significantly affects the critical buckling threshold, restabilization point and wrinkling amplitude. The shear modulus ratio above a critical value prevents the appearance of wrinkles. Effects of the angle between fibers and stretching direction on the oblique wrinkling orientation are carefully examined (see Fig. 1). The findings could provide an effective way to design wrinkle-tunable surfaces for fiber-reinforced or biomimetic membranes.

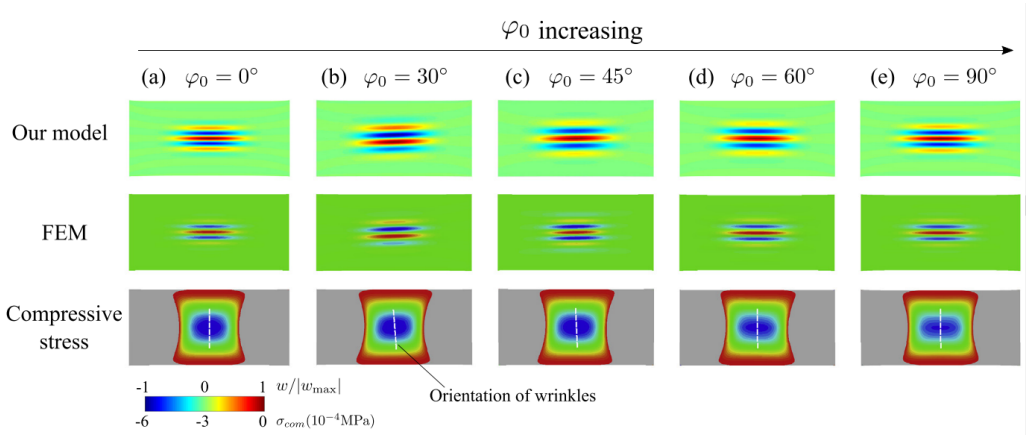

Figure 1. Oriented oblique wrinkles and contours of compressive stresses for various angles φ_0 between material anisotropy and stretching direction.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (Grants No. 11872150, 11772094 and 11890673), Shanghai Rising-Star Program (Grant No. 19QA1400500) and Shanghai Chenguang Program (Grant No. 16CG01).

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An Improved General Regression Neural Network to Analyze the Spatial Variability of SPT in Soil Layer

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Abstract: Research has shown that the soil has its inherent soil variability, and this behavior can be modeled as a random field (Phoon et al. 1999). Vanmarcke and other researchers firstly introduced random field theory into reliability analysis of geotechnical engineering and proposed the concept of correlation distance (Vanmarcke 1977). Yan's study has shown that the correlation distance is different in the vertical and horizontal directions (Yan et al. 2006). To deal with the spatial variability of SPT value in the soil layer, Grytan tries to use more than 36 field SPT values to train the general regression neural network (GRNN) to predict the SPT value of soil in a different position (Grytan et al. 2015). However, the traditional GRNN method just uses the same smooth factor and can't distinguish the difference of correlation distance in the vertical and horizontal direction. In this study, the author proposed an improved general regression neural network (IGRNN), and adds two or more smooth factors into the GRNN, and can consider the difference of correlation distance in a different direction for predicting soil type and standard penetration test (SPT) N (standard penetration resistance) values based on SPT test results. It focuses on soils mainly in the Cotai area, to the south of the Macau University of Science and Technology, to the east of the City of Dreams, and to the north of the Carreira De Tiro & Tenis that comprise fill, marine deposit, and alluvium. A detailed geological and geotechnical investigation of the project and its surroundings was conducted to generalize the subsoil condition of the study area based on soil type and SPT values. To develop the IGRNN model, more than 3000 d SPT values (N) have been collected from 145 boreholes spread over an area of 22 ha. The IGRNN and GRNN prediction were compared with the borehole data and the results showed that the IGRNN method predicts well compared with the actual site investigation data. Therefore, the IGRNN method can better deal with the random field problem comparing with the GRNN method.

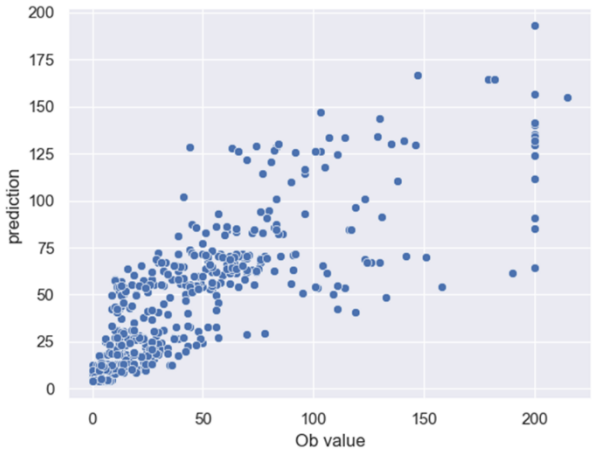

Figure 1. The comparison between actual and predicted values.

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A semi-coupled resolved CFD-DEM method for simulation of Selective Laser Melting

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Abstract: We present a semi-coupled Computational Fluid Dynamics (CFD) and Discrete Element Method (DEM) to solve a class of granular media problems that involve thermal-induced phase changes and particle-fluid interactions. We use Immersed Boundary Method to model the viscous fluids surrounding each solid particle in conjunction with a fictious CFD domain occupying the actual position of particle. Heat transfers between the actual fluids and the fictitious particles are solved as a multiphase problem by the CFD only, to resolve the temperature gradient within the particle and its possible phase change (e.g., melting or partial melting). The mechanical interactions between particles and fluids are considered by coupled DEM and CFD in a conventional manner, by considering interaction forces between the DEM and CFD computations (Hager, 2014). We validated the proposed method with simulations of a typical powder-based selective laser melting process. The simulation results capture key features and observations found in experiments (Trapp *et al.*, 2017) and are quantitatively consistent with existing data. This is part of new research extension of computational granular mechanics.

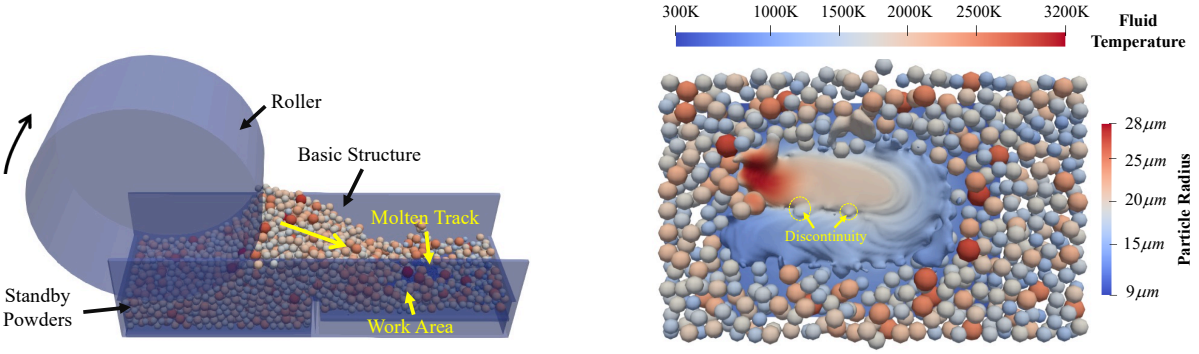

Figure 1. Powder layering process (L) and melting process (R) simulation of SLM

Acknowledgements

The study is financially supported by HKUST-FP907 and F-HKUST601/19. The first author acknowledges the sponsorship of HKPFS on his study.

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Resolved CFD-DEM coupling for modelling two-phase fluids interaction with irregularly shaped particles

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Abstract: We presented a resolved fluid-solid coupling model based on open source CFD-DEM code. This model can solve problems containing two-phase fluids and irregular discrete particles. We combine Computational Fluid Dynamics (CFD) for two-phase fluids and Discrete Element Method (DEM) for particle motion. Resolved CFD-DEM coupling approach helps to get the particle-scale fluid field. Many existing CFD-DEM coupling studies only consider single-phase fluid and spherical particles, which is not capable for solving realistic engineering problems. On the part of DEM, multi-sphere model can represent irregular particles. Therefore, the key challenge is to consider interaction coupling between two-phase fluid and irregular particle. Many benchmark cases are used to validate this model, including settling of irregularly shaped particles in two-phase fluid, and wave impact on a granular slope. The numerical simulation shows the complex fluid-particle interaction can be accurately simulated using the resolved coupling model. The model can be well used to solve large-scale geotechnical problems where irregular particulate media and fluid dynamic load are involved.

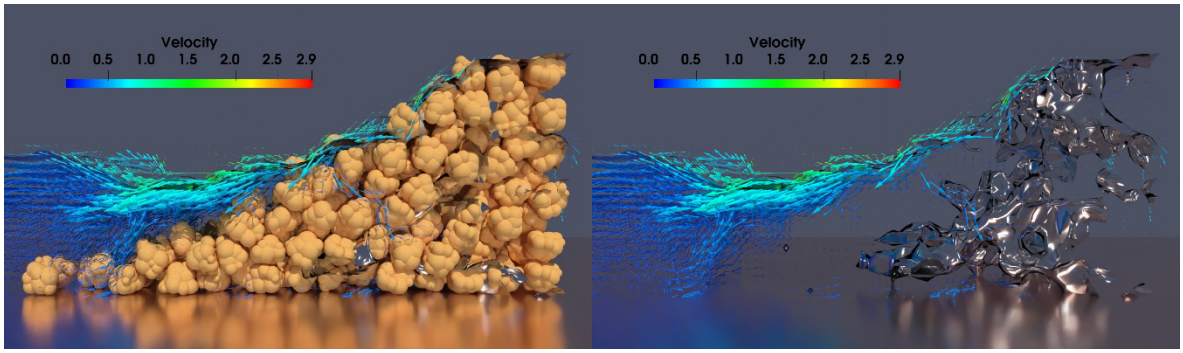

Figure 1. Wave erosion case where (a) shows the water infiltration path in pores, (b) shows the seepage face and bubbles inner the structure by hiding the particles

Acknowledgements

This work was supported by Hong Kong Research Grants Council grant N_HKUST621/18 and 16204618.

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An efficient microfluidic rectifier for Newtonian fluids based on asymmetric converging-diverging microchannels

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Abstract: In this work, we fabricate a microfluidic rectifier for Newtonian fluids using asymmetric converging-diverging microchannels (ACDMCs). Because of the asymmetric structure of the microchannel, the flow resistance depends on flow directions. The highest diodicity for this rectifier is 1.77, which is superior to previous microfluidic rectifiers for Newtonian fluids. An expression for the diodicity is developed on the basis of two scaling laws for the flow resistances in the forward and backward directions.

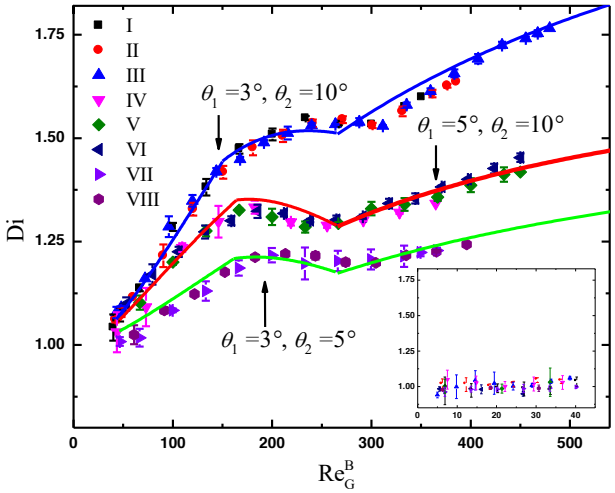

Figure 1. Di as a function of Re_G^B. The inset shows Di for $Re_G^B \le 40$.

Acknowledgements

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Experimental Study of Liquid Micro Jets ablated by Nanosecond Laser Pulse

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Abstract: We performed an experimental study on a water microjet of hundred micrometers in diameter impacted by an NIR nanosecond laser pulse with up to 1100 mJ per pulse. We show this affordable and accessible experimental apparatus captures the essence of waterjet explosion induced by an intense laser impact. The blast breaks the waterjet and generates an expanding gap near the impact point, while a liquid sheet appears right outside the nozzle orifice. The laser ablation causes substantial axisymmetric damage to the nozzle orifice, providing insights on the new mechanism of intense energy transfer to the nozzle orifice, which can be about 40 times of jet diameter away from the energy deposition point.

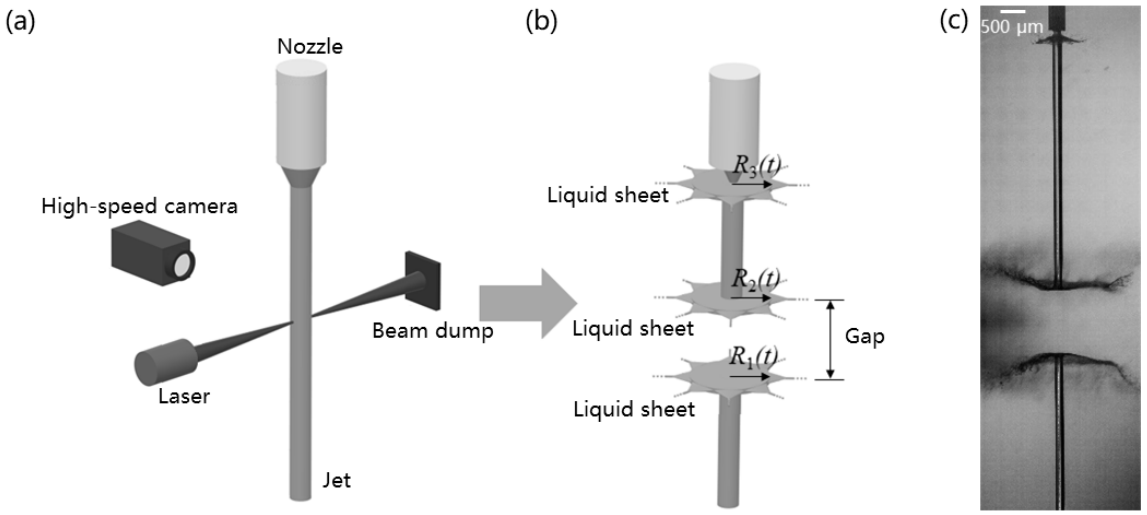

Figure 1. (a) The experimental setup. (b) The blast generates a gap and liquid sheets near both impact point and nozzle orifice. (c) A photo of the phenomenon.

Acknowledgements

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Diffusion-induced stresses in a thin film electrode on an elastic substrate in lithium ion batteries

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Abstract: Diffusion-induced stresses in a thin circular electrode on an elastic substrate under potentiostatic operation is studied. Two different contact problems: adhesive contact and smooth contact are examined. The effect of contact conditions on stress field, displacement and strain energies are evaluated. In present work, numerical calculations are carried out for a cylindrical electrode with ratio of length to diameter L^* 0.1. It is found that difference of normal interfacial stresses between the two cases increases near the edge of contact region. The presence of adhesion increases the absolute value of interfacial radial and hoop stress.

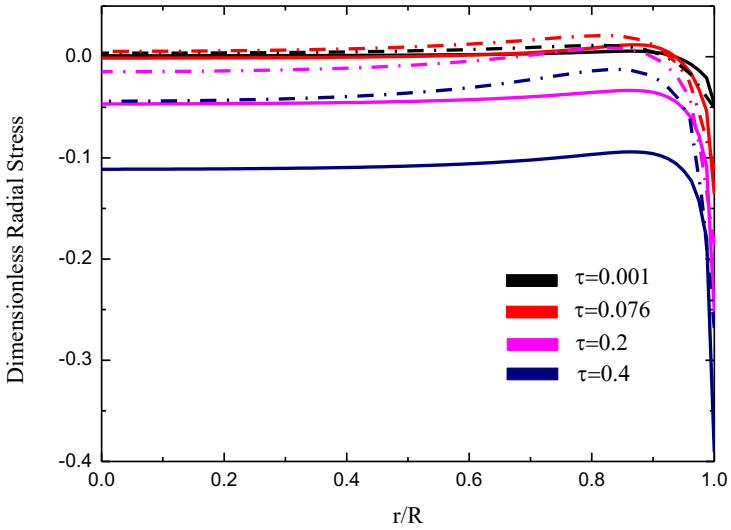

Figure 1. Interfacial radial stresses for a circular electrode resting on half-space substrate under potentiostatic operation. Solid lines: smooth contact; dashed lines: adhesive contact

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Acknowledgements

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PEMFC 快速冷启动时催化层内球形冰粒的非傅立叶热传导及热应力分析

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摘要：低温快速启动是制约质子交换膜燃料电池（PEMFC）汽车大规模商业化的关键技术之一。随着人类对更低温度、更短时间快速启动技术的渴求，基于热能除冰的燃料电池中冰和构件不可避免地受到热冲击作用。为了研究这一问题，本文建立了一个非傅立叶热传导模型，研究了受电池催化层弹性约束的球形冰粒子在热冲击作用下的温度响应，并利用计算出的温度场得到了颗粒内部的热应力分布，分析了热弛豫时间与热流密度对温度响应和热应力场的影响。结果表明，不同于传统傅里叶热传导理论的计算结果，热冲击带来的冰粒膨胀可能导致电池催化层发生严重变形，这对控制冷启动过程中的结构可靠性提出了很大的挑战，为质子交换膜燃料电池的设计和冷启动的控制提供了理论依据。

致谢

感谢国家重点研发计划“燃料电池动力系统多目标优化能量管理”(2018YFB0105501)的资助。

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Intricate evolutions of multiple-period post-buckling patterns in bilayers

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Abstract: Surface instability of compliant film/substrate bilayers has raised considerable interests due to its broad applications such as wrinkle-driven surface renewal and antifouling, shape-morphing for camouflaging skins, and micro/nano-scale surface patterning control. However, it is still a challenge to precisely predict and continuously trace secondary bifurcation transitions in the nonlinear post-buckling region. Here, we develop lattice models to precisely capture the nonlinear morphology evolution with multiple mode transitions that occur in the film/substrate systems. Based on our models, we reveal an intricate post-buckling phenomenon involving successive flat-wrinkle-doubling-quadrupling-fold bifurcations (see Fig. 1). Pre-stretch and pre-compression of the substrate, as well as bilayer modulus ratio, can alter surface morphology of film/substrate bilayers. With high substrate pre-tension, hierarchical wrinkles emerge in the bilayer with a low modulus ratio, while a wrinkle-to-ridge transition occurs with a high modulus ratio. Besides, with moderate substrate pre-compression, the bilayer eventually evolves into a period-tripling mode. Phase diagrams based on neo-Hookean and Arruda-Boyce constitutions are drawn to characterize the influences of different factors and to provide an overall view of ultimate pattern formation. Fundamental understanding and quantitative prediction of the nonlinear morphological transitions of soft bilayer materials hold potential for multifunctional surface regulation.

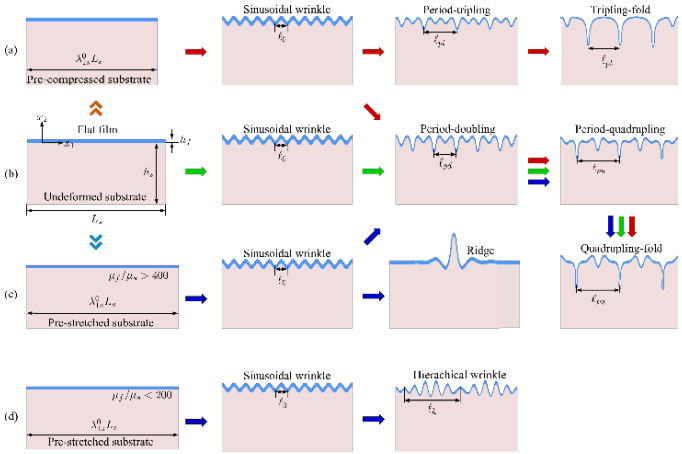

Figure 1. Schematic instability pattern evolutions of film/substrate system: (a) flat-wrinkle-tripling-fold transition with substrate pre-compression, (b) flat-wrinkle-doubling-quadrupling-fold transformation under direct compression, (c) flat-wrinkle-ridge transition with substrate pre-stretch and large modulus ratio, (d) flat-wrinkle-hierarchical transition with substrate pre-stretch and small modulus ratio.

Acknowledgements

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Micromechanical Investigation of the At-rest Earth Pressure Coefficient of Granular Soil

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Abstract: The earth pressure coefficient at rest (K_0) is a key parameter for estimating the initial earth pressure distribution in a range of geotechnical applications. Classical Jaky's equation has been widely used to calculate K_0 in engineering practice. Although Jaky's equation can provide a good estimate of the at-rest earth pressure distribution in granular soil in some situations, the assumption behind the Jaky's model is not sound from a theoretical point of view, and the good prediction of Jaky's equation is somewhat coincidental. This study conducts a micromechanics-based analysis of the at-rest earth pressure coefficient in which the fabric anisotropy inherent in in-situ soils and the contact conditions at particle level are considered. Comparison between the predictions from the micromechanical model and from Jaky's equation is made, and the influence of anisotropy and contact conditions is examined. The present study provides some new insights into the fundamental aspect of the earth pressure coefficient at rest.

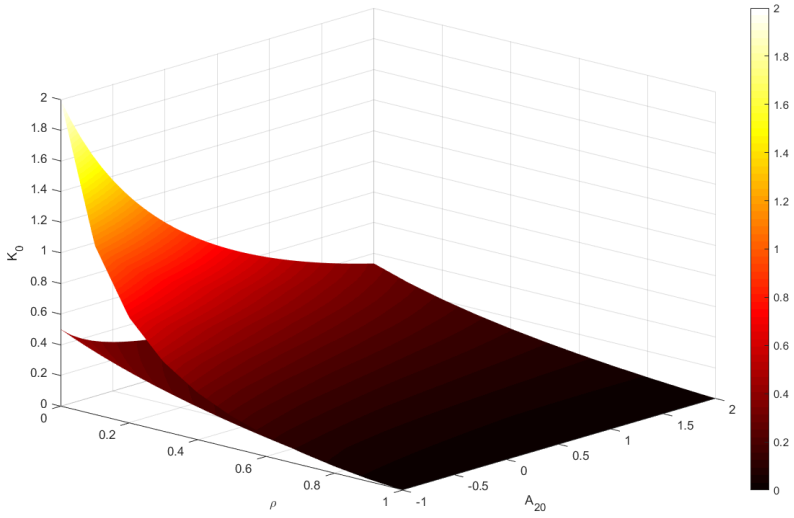

Figure 1. Earth pressure coefficient at rest based on micromechanical analysis

Acknowledgements

Financial support provided by the Research Grants Council of Hong Kong (No. 17206119) is gratefully acknowledged.

Estimation model of excess pore water pressure in front of a TBM in saturated sand

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Abstract: Unfavourable excess pore water pressure (EPWP) will be inevitably generated when tunnelling with a tunnel boring machine (TBM) in saturated sand, which is a critical factor affecting the stability of the tunnel face. Accurately estimating the magnitude of the EPWP thus has profound significance in stabilizing the tunnel face and minimizing deformations during the tunnel boring process. This study presents the development of an explicit computational model consisting of the drilling model and standstill model for variations of the EPWP using genetic programming (GP) approach. The data sets were collected from the field monitoring project during construction of the Green Hart Tunnel (GHT) in Netherlands. The EPWP was quantified with three selected input variables including distance from monitoring cross-section (MCS), drilling or standstill duration, and ratio of distance from tunnel axis to tunnel outer diameter. Based on performance evaluation and comparison analysis, the proposed model has been verified highly successful in capturing variations of the EPWP. The importance of each input variable on the output and their relationships were investigated. It is shown that the proposed model is capable of providing explicit and accurate estimation of the EPWP, which can provide quick, inexpensive and effective references for the practitioner to achieve better risk-based decision making.

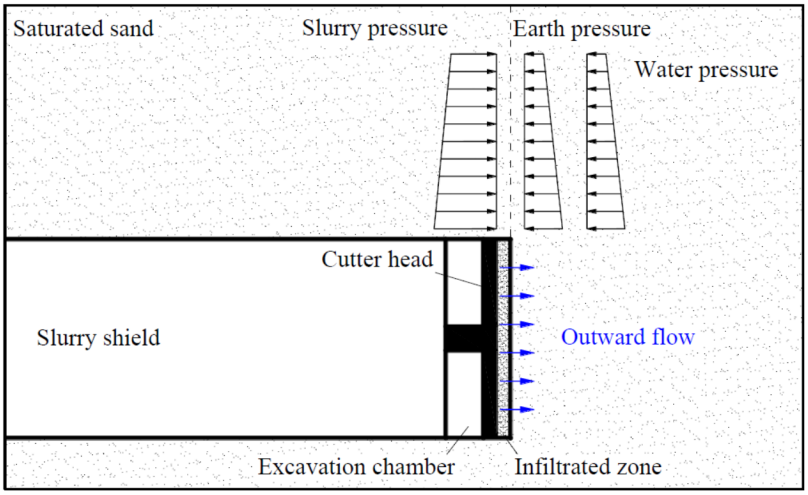

Figure 1. Generation of outward flow from the excavation chamber of slurry shield

Acknowledgements

The authors wish to thank the support founded by The Science and Technology Development Fund, Macau SAR (File no. 0035/2019/A1)

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Geotechnical and microstructural properties of marine clay treated by nano zero-valent iron (nZVI)

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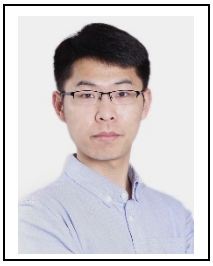

Abstract: The nano zero-valent iron (nZVI) has been proved as an excellent remediation material and exhibited enormous potential in soft-soil enhancement applications (Chen et al. 2019a, b). This article presents a series of the geotechnical and microscale analysis of nZVI treated marine clay. It indicates that nZVI perform a significantly positive effect on contamination remediation, soil deformation and shear strength. The micro-analysis noted that large particle size, branched aggregates and crosslink microstructure could be the main interaction mechanism of marine clay treated by nZVI.

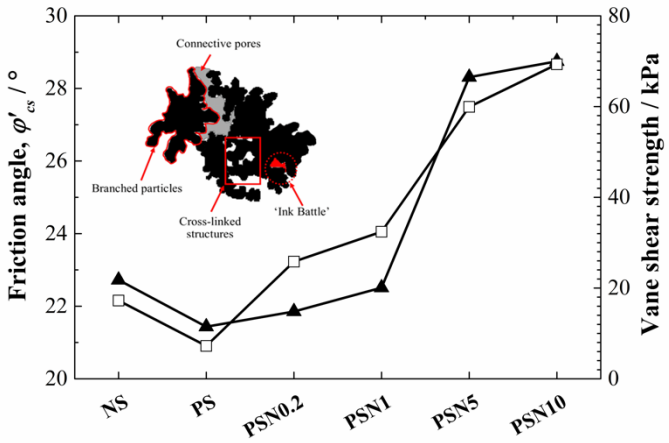

Figure 1. Variation in friction angle and vane shear strength of marine clay treated by nZVI, and microstructural illustration of treated soil based on micro-analysis.

Acknowledgements

The authors wish to thank the financial support funded by The Science and Technology Development Fund, Macau SAR (File no. 0035/2019/A1 and 0026/2020/AFJ) and University of Macau (File no. MYRG2018-00173-FST).

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Characterization of Microstructure and Particle Breaking of Carbonate Sand

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Abstract: Carbonate sand particles have a complicated shape and well-developed internal pores, which result in different engineering characteristics as compared to quartz sand (Coop, 1990). To achieve a deeper understanding of the physical and mechanical properties of carbonate sand, three-dimensional images of carbonate sand particles were obtained with the aid of high-precision CT scanning. A new image processing method was proposed to identify and characterize the morphology of each single particle in 3D images and their internal pores. In-situ CT scanning of single particle was further conducted to examine the crack growth and fragment morphology evolution during crushing test of carbonate sand. Based on the CT data of carbonate sand particles, a coupled discrete-continuous analysis (FDEM) model (Munjiza, 2004) was established to accurately simulate the crushing process, and the influence of pore structure in carbonate sand particles on its crushing behaviour was explored. The results show that the porosity and the pore structure of carbonate sand particles have a direct influence on the crushing strength and crack distribution.

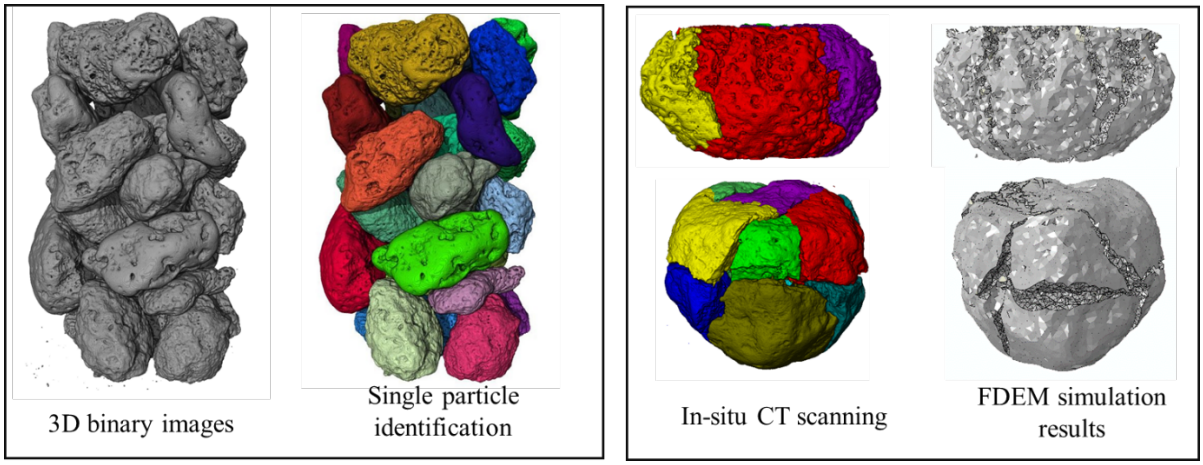

Figure 1. Single particle identification (L) and the comparison of in situ test and FDEM simulation results (R)

Acknowledgements

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Numerical modelling of slurry infiltration in granular materials

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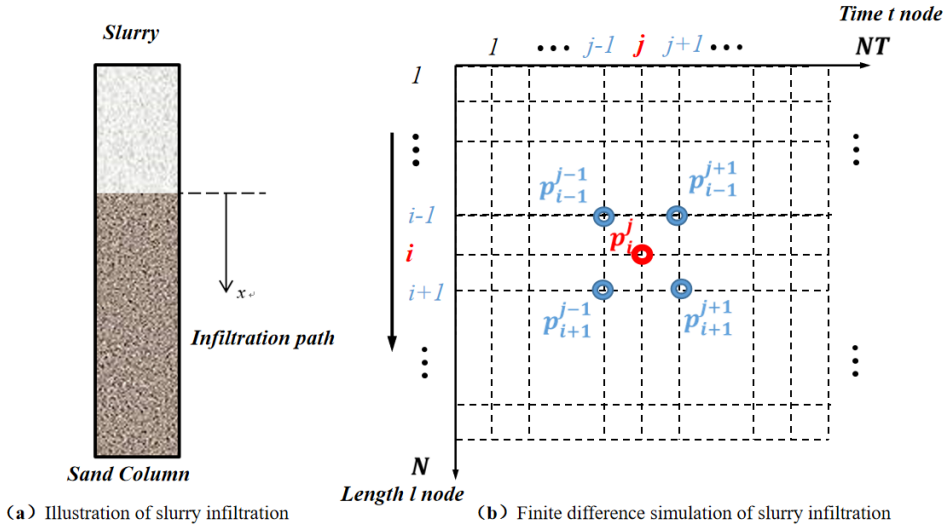
Abstract: In civil engineering projects such as the slurry shield tunnelling, slurry trench, and pile construction, the slurry particles deposition, the soil deformation and the slurry seepage are all concerns of engineers. Quantifying these physical quantities helps guide the design and construction in the engineering practice. In order to investigate the slurry infiltration process, the researcher deducted mathematics governing equations and applied Finite Difference Method (FDM) in simulating infiltration process, while the fluid continuity equation in Biot theory and particle mass conservation law of the particle dispersion equation have been coupled. From this numerical analysis, multiple physical behaviours of slurry infiltration including soil deformation, slurry seepage and particle dispersion can be described accordingly. The comparative analysis between test and numerical analysis is consistent, indicating that this numerical solution is capable of predicting complicated behaviours in slurry infiltration.



(a) Illustration of slurry infiltration (b) Finite difference simulation of slurry infiltration

Figure 1. Illustration of slurry infiltration and FDM simulation of infiltration

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