Proceedings of

The 26th Annual Conference of HKSTAM 2023
The 18th Shanghai – Hong Kong Forum on Mechanics and Its Application

April 15, 2023

The Hong Kong Polytechnic University, Hong Kong

Editors

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PREFACE

The 26th Annual Conference of HKSTAM 2023 in conjunction with the 18th Shanghai–Hong Kong Forum on Mechanics and Its Application is held in The Hong Kong Polytechnic University on April 15, 2023. 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), The Hong Kong Polytechnic University (PolyU), and The Hong Kong University of Science and Technology (HKUST), and sponsored by Baidu Inc. The conference aims to provide a platform for all scientists, engineers, and mathematicians working on mechanics and related areas to share, communicate and exchange ideas, and to enhance co-operations within relevant parties. This proceeding consists of 76 abstracts, including 32 from SSTAM, 43 from HKSTAM, and 1 from Baidu. The conference presents 5 Distinguish Lectures in the morning, i.e., by Prof. Yi-Kuen LEE from The Hong Kong University of Science and Technology, Prof. Shijun LIAO from Shanghai Jiao Tong University, Dr. Qipeng CHEN from Baidu, Prof. Wei HONG from Southern University of Science and Technology, and Prof. Kai Leong CHONG from Shanghai University. It also contains 14 parallel sessions arranged in the afternoon.

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 of SSTAM for his great effort for co-organization in Shanghai; Ms. Zhao HOU of PolyU for her help in communicating with various parties. The Society also wishes to thank the generous support from Institution Members of HKSTAM.

On behalf of and for the Executive Committee

Gang WANG
President of HKSTAM
Professor and Associate Head
Department of Civil and Environmental Engineering
Hong Kong University of Science and Technology

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Conference Program

April 15, Saturday, Morning (GH201)

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9:00 – 9:15am	**Opening addresses** **MC: Prof. Hui Tang, Secretary of HKSTAM** **Prof. Gang Wang (王剛)** **President of HKSTAM 香港力學學會理事長** **Prof. Shijun Liao (廖世俊)** **Vice President of SSTAM 上海市力學學會副理事長**
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April 15, Saturday, Afternoon (Parallel Sessions A1 to C1)

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2:15 – 2:30pm	S.H. Yang#, X.W. Deng Application of machine-learning based optimization framework to offshore wind farm: layout and yaw control optimization	H.H. Huang#, L. Fu A high-order shock-capturing DG method based on the TENO scheme	X.L. Chen#, L. Fu Linear response analysis of compressible turbulent channel flows
2:30 – 2:45pm	L.W. Zeng#, W. Wang, Y. Liu, H. Tang Flow induced vibration of a cactus-shaped cylinder with three/four ribs	X.C. Feng#, H. Xu Forecasting of ocean wave height using a multi-recurrent neural network structure	F.W. Zhao#, W.K. Yeung, Z.K. Wang, L. Li, H. Tang Deep reinforcement learning guided transverse force reduction for a bluff body in wake flow
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presenter

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presenter

April 15, Saturday, Afternoon (Parallel Session G1)

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presenter

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presenter

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presenter

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presenter

April 15, Saturday, Evening

5:15 – 5:30pm	**Closing Ceremony and Award Presentation [GH201]**
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6:30pm	**Banquet [Ju Yin House Seafood Restaurant (聚賢樓), 4/F, Communal Building, PolyU]**

~ Closure of the conference ~

Distinguished Lecture I

Prof. Yi-Kuen LEE (李貽昆)

Prof. Yi-Kuen Lee earned his Bachelor's degree from National Taiwan University in 1992. He then pursued his Master's degree under the supervision of Prof. Yih-Hsing Pao (a member of the US National Academy of Engineering and Academia Sinica) at the Institute of Applied Mechanics, NTU. Dr. Lee completed his Ph.D. in Mechanical Engineering, specializing in MEMS, under the guidance of Prof. Chih-Ming Ho at the University of California, Los Angeles (UCLA) in 2001. Dr. Lee has held positions in the Department of Mechanical and Aerospace Engineering, Chemical Engineering, and Bioengineering at the Hong Kong University of Science and Technology (HKUST). He previously served as the President of the Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM) and co-founded the IEEE NEMS conference. He has been a participant and organizer of several international micro and nano conferences, including ICMAN2016, APCOT2018, IEEE MEMS, and Transducers. He took charge of constructing NFF2.0 for HKUST, the micro and nano processing platform at HKUST's Guangzhou campus. In 2021, he became a member of the Executive Committee of the Hong Kong ITF InnoAir research center in collaboration with UC Berkeley, Hong Kong Center for Construction Robotics (HKCRC). Currently, his primary research focus lies in CMOS MEMS sensor theory and novel microfluidics technology (personalized Microfluidic Elasto-Filtration) for smart buildings and smart construction and biomedical applications.

Advancements in MEMS thermal sensors for smart buildings and smart construction in the era of AIoT

Yi-Kuen LEE

Department of Mechanical & Aerospace Engineering, Department of Chemical Engineering and Bioengineering, Hong Kong Center for Construction Robotics, Hong Kong University of Science and Technology, Hong Kong SAR, China.

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Over the past two decades, my research lab at HKUST has dedicated to the fundamental study of microfluid mechanics and microscale heat transfer, encompassing modeling, simulation, and development of microfabrication processes for various MEMS/microfluidic applications. We have successfully developed silicon-glass microchannels integrated with microheaters, micro temperature sensors, and micro pressure sensors, allowing us to investigate the size effects in single-phase and two-phase heat transfer.

Furthermore, we have created microbubble actuators to study complex biofluids, such as DNA solutions, and developed bubble-actuator-enhanced optical biosensors for bacteria detection. In recent years, we have applied our foundational research to develop state-of-the-art thermal MEMS sensors, including thermal flow sensors, human thermal comfort sensors (PMV), micro BTU sensors, thermal accelerometers, and thermal gyroscopes. These devices leverage heterogeneous integration (HI) of semiconductor foundry processes (TSMC/UMC/Global Foundries 0.18μm CMOS, InvenSense 3D CMOS MEMS foundry processes) and HKUST NFF cleanroom facilities.

Employing applied mechanics, we have developed and validated compact models and SPICE models for these thermal MEMS, achieving speeds 3 to 6 orders of magnitude faster than conventional computer models. These models facilitate rapid design optimization of the devices and their integration into semiconductor EDA software (such as Cadence) for CMOS MEMS design in conjunction with analog IC design using semiconductor foundry processes. The optimized CMOS MEMS thermal sensors outperform products from leading international companies, including Analog Devices Inc.'s MEMS motion sensors. Additionally, the sensitivity of our optimized CMOS MEMS thermal flow sensor surpasses that of Laser Doppler Anemometry (LDA) in the US National standard at NIST.

As we move toward the era of AIoT, these CMOS MEMS sensors, integrated with edge AI devices, show immense potential for smart buildings and smart construction applications. Advanced 3DIC integration in the semiconductor industry, such as TSMC's 3Dfabric platform, will further unlock their capabilities.

Distinguished Lecture II

Prof. Shijun LIAO (廖世俊)

Dr. Shijun Liao is a distinguished professor, School of Navel Architecture Ocean and Civil Engineering, Shanghai Jiaotong University, China. He is currently the head, State Key Laboratory of Ocean Engineering, China.

Prof. Liao is the founder of the “homotopy analysis method” (HAM), an analytic approximation method for highly nonlinear problems. Today, the homotopy analysis method has been widely used by researchers all over the world. Besides, he proposed a new strategy to gain reliable numerical simulations of chaotic systems, called the “Clean Numerical Simulation” (CNS). The CNS provides a totally new tool to investigate chaos and turbulent flows and to attack some open questions.

Prof. Liao has published two monographs and about two hundred articles. His books and publications have been cited 20163 times in scholar-google. He was awarded “Shanghai Award in Natural Science” and “National Award in Natural Science”. He was listed among “the Highly Cited Researcher” in 2014, 2015 and 2016.

Ultra-chaos, statistics instability and non-reproducibility

Shijun LIAO

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Abstract: The sensitivity dependence on initial condition (SDIC) was first discovered by Poincare in 1890 and then rediscovered by Lorenz in 1963 with a popular name, i.e. "butterfly-effect", which reveals the trajectory instability of chaos. It was Lorenz who first discovered that chaotic trajectory has also sensitivity dependence on artificial factors (SDAF) such as numerical algorithms, time-step and so on, if single or double precision is used. As a result, numerical noise of a chaotic simulation given by a traditional algorithm with single or double precision increases exponentially so that such a chaotic simulation is a mixture of the true physical solution and the false numerical noise, which are mostly at the same order of magnitude. Even so, such kind of chaotic simulations badly polluted by numerical noise are widely used in practice to calculate statistics, mainly due to the hypothesis that statistics of chaos are stable, say, insensitive to small disturbances. Unfortunately, rigorous proof of this hypothesis has never been given. I proposed the so-called "clean numerical simulation" (CNS) in 2009, which can guarantee the convergence of chaotic trajectory in a long enough interval of time. Thus, convergent trajectory given by CNS can be used as benchmark solution to check the statistics stability of chaotic systems. It is found that statistics of some chaotic systems are unstable, called ultra-chaos. Besides, it is further found that ultra-chaos widely exists in chaotic dynamic systems. Note that it is impossible to repeat any physical experiments and/or numerical simulations of an ultra-chaos. Unfortunately, reproducibility is a corner-stone of modern scientific method, since it means that scientific laws are invariant across time and space. Thus, ultra-chaos might reveal some restrictions, limitations and incompleteness of modern scientific method, which might become a great challenge for us.

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Liao, S.J. (2017), "On the clean numerical simulation (CNS) of chaotic dynamic systems," *Journal of Hydrodynamics*, **29**(5), 727–747

Liao, S.J. and S.J. Qin (2022), "Ultra-Chaos: an insurmountable objective obstacle of reproducibility and replication," *Advances in Applied Mathematics and Mechanics*, **14** (4), 799–815.

Distinguished Lecture III

Dr. Qipeng CHEN (陳其朋)

Dr. Qipeng Chen is currently Senior Technical Product Manager of Baidu PaddlePaddle. He obtained his B.Eng. degree in Materials Science and Engineering from Huazhong University of Science and Technology and Ph.D degree in Materials Processing Engineering from Tsinghua University. He has been working on multi-scale coupled numerical simulation of fluid flow, heat transfer, phase transformation and grain growth during alloy solidification. His current research interests include PINN method and FEM/FVM method in the field of fluids, heat transfer and structure.

Application of physics-informed neural network on partial differential equation solving

Y. ZHOU*[1], Q. CHEN#[1], Y. ZHANG[1], Z. WANG[2], X. HU[1] and Q. ZHAO[1]

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[2] Department of Mechanical Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong, China

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Presenter: chenqipeng@baidu.com

Partial Differential Equation (PDE) solving is a thriving branch in fluid and solid mechanics research, which contributes greatly to the structural design and optimization. Typically, classical numerical methods, i.e., Finite Element Method (FEM) and Finite Volume Method (FVM), are mostly utilized to handle PDE, but their computing efficiency is significantly restricted by the factors, like sophisticated mesh generating and large linear equations solving. This significantly hinders the advancement of computer-aided design, especially in the fields like structural optimization that demand intensive computing. Recently, Physics-Informed Neural Network (PINN) has shown its unique superiority on PDE solving in light of its natural parallelism and physical-law embedding. The usage of PINN on some simple mechanics problems, i.e., steady viscous flow (Chuang et.al, 2022) and 2D structure deflection (Vahab et.al, 2022), has demonstrated its success in handling PDEs. In this paper, we will go deeper into PINN's potential for solving more challenging mechanical problems that have not yet been resolved: unsteady viscous flow and 3D Euler beam deflection. This PINN study will provide insight into its potential further applications for structural optimization. The code is developed based on Baidu PaddlePaddle framework and can be accessed on: https://aistudio.baidu.com/aistudio/projectdetail/4178470 (flow) and https://aistudio.baidu.com/aistudio/projectdetail/5785287 (structure).

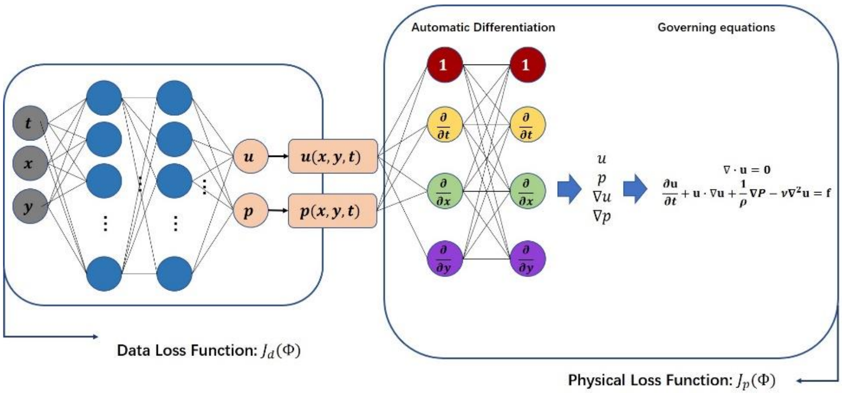

Figure 1. Physics-Informed Neural Network (Navier-Stokes equation)

Acknowledgements

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Vahab, M., Haghighat, E., Khaleghi, M., & Khalili, N. (2022). A physics-informed neural network approach to solution and identification of biharmonic equations of elasticity. *Journal of Engineering Mechanics*, 148(2), 04021154.

Distinguished Lecture IV

Prof. Wei HONG (洪偉)

Wei Hong is currently Professor and Associate Chair of the Department of Mechanics and Aerospace Engineering at Southern University of Science and Technology (SUSTech), and Fellow of ASME. Wei received both B.S. and M.S. degrees from Tsinghua University, and Ph.D. in Engineering Sciences from Harvard University in 2006. Wei worked in the Department of Aerospace Engineering at Iowa State University and was tenured and promoted to Associate Professor in 2014. He held joint appointment from Hokkaido University since 2015 and was appointed as Associate Professor and later as Professor. He joined SUSTech in 2018. Wei's research covers a broad spectrum in mechanics, including solid mechanics, fracture mechanics, microstructure evolution, multiphysics modeling, and his recent research is focused on polymer physics, soft matter mechanics, adhesion, dielectric breakdown, and surface instabilities.

Chemically identical gels

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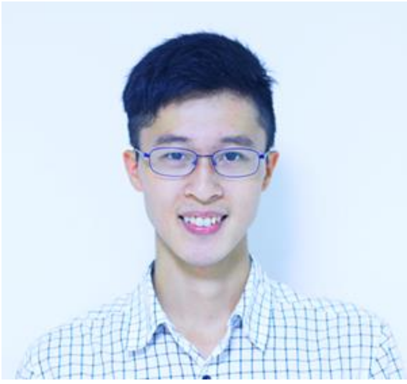
Composed mostly of solvent molecules and a loosely crosslinked polymer network, a polymeric gel appears and feels like a liquid. Questions naturally arise: Are the mechanical properties fully determined by its chemical composition, just like a liquid solution, or would the synthesis condition or process affect its network structure and further the macroscopic properties? Through carefully planned experiments, we systematically studied the mechanical properties of a set of polymeric gels with identical chemical compositions but prepared through different processes. Strong dependences of the mechanical properties on the synthesis conditions were identified, and the results were found to follow a set of scaling laws. From basic theories and fundamental yet intuitive hypotheses characterizing the network topology and structural evolution, we derive the scaling laws which successfully capture the experimental observations. We further studied the fracture of these chemically identical gels and found some intriguing relations between fracture energy and synthesis processes. These findings provide insights to the mechanisms in the formation of network structures and topologies at synthesis, and their profound effects on macroscopic properties. The theory established may influence the design and synthesis of polymeric materials with extraordinary performances.

Distinguished Lecture V



Prof. Kai Leong CHONG (莊啟亮)

Kai Leong CHONG is professor of mechanical engineering at Shanghai University, working on the fields of thermal turbulence and multiphase flow. He received his Ph.D. degree from The Chinese University of Hong Kong under the supervision of Prof. Ke-Qing Xia. Prior to joining Shanghai University, he was a postdoctoral researcher in Physics of Fluids group at University of Twente under the supervision of Prof. Detlef Lohse. He has received several awards and fellowship including National Science Fund for Excellent Young Scholars (Overseas) and Croucher Fellowships for Postdoctoral Research. He has published more than 40 papers in refereed journals including Science Advances, Nature communications, PNAS, Physical Review Letters and Journal of Fluid Mechanics, etc. His works on transmission of respiratory diseases from fluid mechanics perspective has been selected as the cover of Physical Review Letters and ESI highly cited paper.

Respiratory disease transmission from fluid mechanics perspective

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Abstract: Respiratory events such as breathing, speaking, coughing, and sneezing can result in the release of pathogen-laden droplets or aerosols, leading to the potential spread of respiratory diseases. The underlying flow physics of viral particle propagation in the air is crucial to understand and mitigate the spread of diseases. However, this is a challenging process due to the complex interaction between the suspended particles, turbulent flow, vapor field, and ambient temperature fields. In this study, we used direct numerical simulations and Lagrangian statistics to investigate the transport of small droplets emitted from the body during a turbulent humid respiratory puff. Our results demonstrate that the small droplets are engulfed by the puff, leading to a significant increase in their lifetimes by many orders of magnitude. As a result, these droplets can travel much further during respiratory events compared to larger droplets that typically travel ballistically in the air. Our findings have important implications for the resumption of normal indoor activities in the post-pandemic phase. They provide guidance on how to rely on the natural way of precautions based on the knowledge of fluid mechanics to manage potential outbreaks of respiratory diseases.

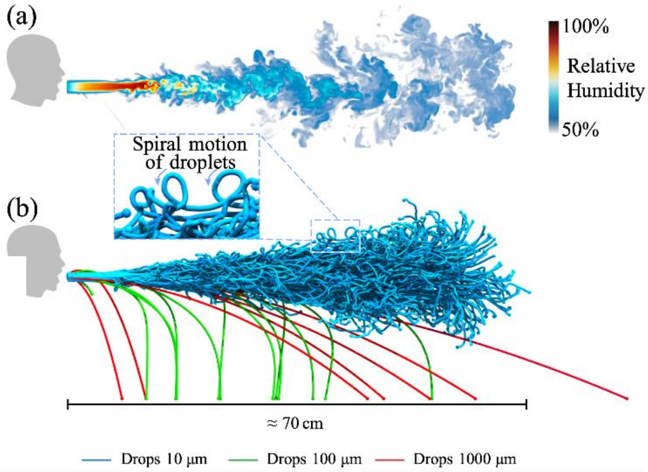

Figure 1. Propagation of the vapour field (a) together with the trajectories of the respiratory droplets (b).

Acknowledgements

This work was supported by the Natural Science Foundation of China under Grant Nos. 11988102, 92052201, 91852202, 11825204, 12032016, 12102246, and 11972220, the Shanghai Science and Technology Program under Project No. 20ZR1419800, and by the ERC Advanced Grant DDD, Number 740479 and by several NWO grants.

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Dancing bubble and filamentation instability

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Abstract: Many intriguing phenomena will occur in the mesoscopic fluids by utilizing various physical fields, resulting from its unique length scale, and holding promising for the diverse applications. Two examples will be presented in this talk. In the first example, arising from the strong photothermal response of near-infrared laser in pure water and the efficient heat conduction at the solid/liquid interface, a temperature inversion layer is formed, and the dancing bubble is produced, enabling the precise control of underwater bubbles. For the second example, by taking advantage of the advanced thermal drawn process and the templated film, the filamentation instability is controlled in terms of the final periodicity of the ordered filament array, paving the way for nano-optics and wearable functional fabrics.

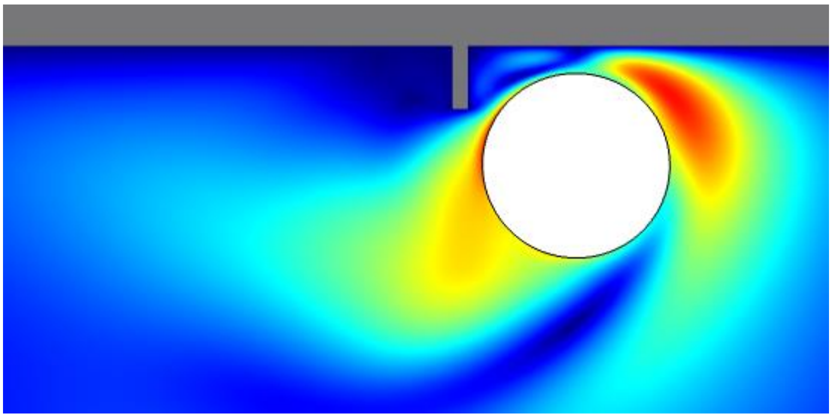

Figure 1. The dancing bubble

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Application of machine-learning based optimization framework to offshore wind farm: layout and yaw control optimization

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Abstract: The close cluster of the turbine for sharing the infrastructure will incur a significant wake effect of velocity deficit and added turbulence at the downstream turbines, thus the loss of power production and increase of the fatigue load. The mainstream approaches to resolving the wake problem can be categorized into two types in accordance with the implementation phase, layout design and yaw control. However, most of the previous research on the control strategy is confined to the regular wind farm layout, which questions the real benefit of control optimization to the optimized configuration [1]. Meanwhile, the investigation of the layout design usually ignores the effects of cooperative control based on the assumption of traditional greedy control [2-3]. This study will conduct a two-stage optimization framework coupling layout and control. The optimized layout design is obtained without considering the potential of control optimization, and then the cooperative control is applied to the optimized layout in collaboration with some novel control schemes reducing the optimization dimensions. The genetic algorithm combing with the ANN wake model is employed in the design stage to implement layout optimization. In the operation stage, a double-layer machine learning framework will realize accurate and efficient cooperative control, as shown in Figure 1. Meanwhile, three control schemes will be deployed to different layouts to discuss their applicability. The results show that the proposed coupling optimizations can simultaneously realize the layout and control optimization. The layout design is deemed the primary wake mitigation strategy. The row-based scheme applies to the regular layout, while the column-based control scheme can bring more benefits to the optimal layout.

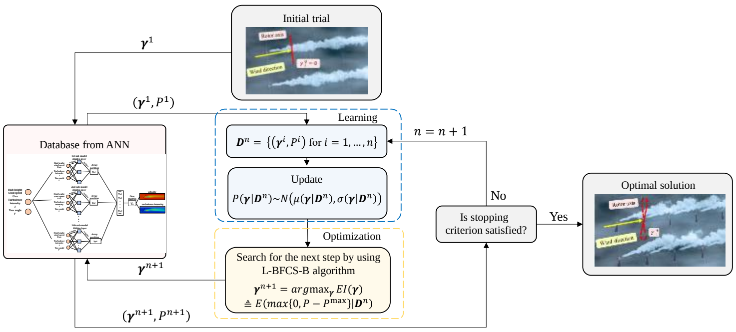

Figure 1. Double-layer machine learning control framework.

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Flow induced vibration of a cactus-shaped cylinder with three/four ribs

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Abstract: Motivated by the succulents of Euphorbia Trigona and Euphorbia Abyssinica, we experimentally and numerically investigated the flow-induced vibration (FIV) performance of a nature-inspired cylinder with three or four ribs. The effect of angles of attack (AOAs) on its FIV and hydrodynamic performance was also examined, with a plain cylinder serving as a benchmark. As schematically illustrated in Figure.1, the FIV system was tested in a water tunnel with the water flow speed varying from 0.066 to 0.517 m/s, corresponding to a diameter-based Reynolds number Re $\approx$ 2,900 ~ 24,500. It was found that, compared with the plain cylinder, the three-rib cases suppress the cylinder's oscillation at low AOAs (0°~30°) while promoting galloping at high AOAs (45°~ 60°). This is because the flow separation for three-rib cases was advanced at higher AOAs, causing a larger curvature of shear layers and flow reattachment. As such, the pressure difference synchronizes with the oscillation and provides a more significant excitation to the FIV system. Cylinder's oscillation amplitude was almost entirely suppressed for the three-rib cases at low AOAs and four-rib cases at high AOAs (30°~ 45°), which is attributed to the delay of flow separation and quite symmetrical pressure distribution in the near wake. Besides, a typical vortex-induced-vibration (VIV) response occurs to the four-rib cases at low AOAs (0°~ 15°), which is companied by a symmetry break and hence a P+S vortex shed mode.

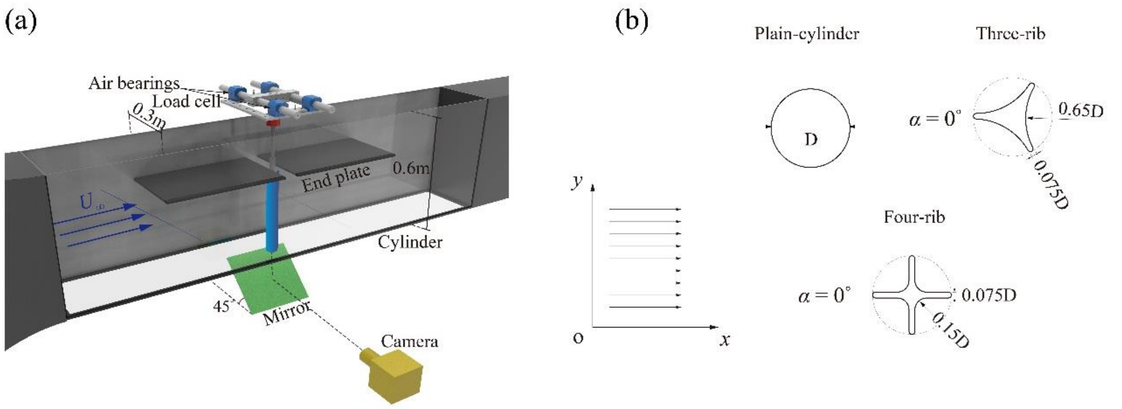

Figure 1. (a) test rig installed in a closed-loop water channel; (b) the sketch of the typical tested cases.

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Heat Transfer Application of Dual Sweeping Impinging Jets at Narrow Spacing

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Abstract: A sweeping jet emanating from a fluidic oscillator is preferred in comparison to a steady circular jet for uniform heat transfer enhancement of the targeted surface. In multi sweeping jet configuration, this inherent benefit of a sweeping jet may self-undermines owing to the asynchronous behaviour of adjacent sweeping jets. Recently, a novel pair of fluidic oscillators synchronized two sweeping impinging jets by fusing their nearest-feedback channels and forming dual-sweeping jets. This study explores its heat removal potential at narrow spacing and compares to dual-steady circular jets using T-type thermocouples and flat surface impingement. A synchronized pair of fluidic oscillators of hydraulic diameter 5mm and aspect ratio of unity was used for impinging relatively cool air upon the hotbed at Re 15000 and jet-to-plate spacing of 2.0, 1.0, and 0.5 hydraulic diameters. It was found that the dual sweeping jets retain their advantage along the sweeping direction except at the stagnation region while the dual steady jets substantially outperformed in off-axis direction. Additionally, the sweeping jets are much better at narrow spacing and in-phase motion of dual sweeping jets helped enhancing the heat transfer capacity of a region in-between the adjacent fluidic oscillators. Hence, this pair of synchronized fluidic oscillators is a rightful candidate for more uniform impingement heat transfer in multi-jet configuration.

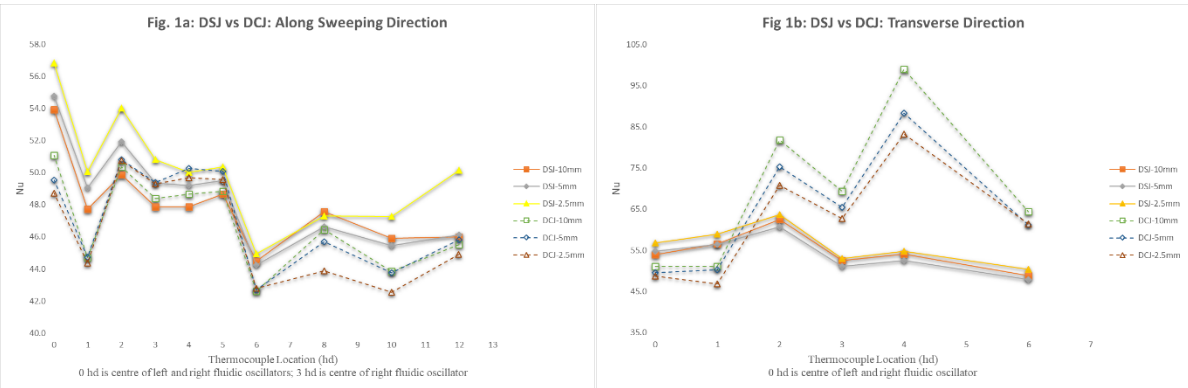

Figure 1. Comparison of Dual Sweeping Jet (DSJ) and Dual Circular Jet (DCJ) for three jet-to-plate spacing

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Prediction of incompressible turbulent channel flow using limited measurements based on the resolvent analysis

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Abstract: In many cases of numerical simulation and experiments, the turbulent information is only partially available due to inaccurate numerical models or insufficient sampling points. Predicting the missing dynamics of turbulence with limited measurements is thus important in engineering and scientific research. The resolvent analysis is known to build the linearized relationship of the response and the nonlinear forcing from the Navier-Stokes equations [1]. The linear operator can be used to reconstruct the coherent turbulent structures [1] and predict the turbulence with limited measurements [2], which, however, can be directly applied only when the predicted flow structures are strongly related to the measured flow. In this study, we propose to predict the turbulence with the modeled forcing, whose energy of the leading mode and its correlation with the sequential modes are modified based on the near-wall estimations from the resolvent analysis. Using the new method, the measurements can be located far away from the wall while providing accurate prediction. From Fig. 1, the new method efficiently predicts both the fluctuation statistics and instantaneous footprints at the near-wall region with the measurements located at the logarithmic region.

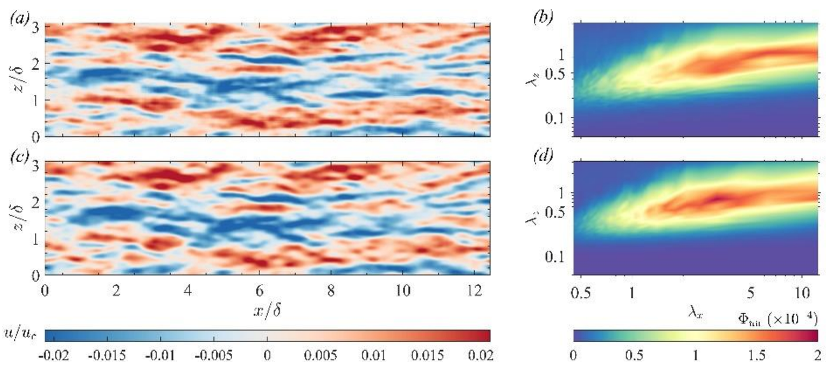

Figure 1. Comparisons of the footprint of the large-scale motions at the measured layer of $y^+ = 100$ to the prediction layer of $y^+ = 50$ in channel flow with $Re_\tau = 550$ from DNS (a,b) and the predicted results (c,d). Panels (a,c) are the instantaneous velocity fluctuations and (b,d) are the corresponding energy spectral densities.

Acknowledgements

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Green functions for the hydroacoustic waves in a compressible inviscid fluid covered by an elastic thin plate

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Abstract: Hydroacoustic wave motion due to a point source submerged in a compressible fluid of finite depth is investigated. The inviscid and homogenous fluid is covered by a thin ice sheet modeled as the Euler–Bernoulli elastic plate. Within the framework of potential flow theory, the wave equation is taken as the governing equation with the linearized boundary conditions for small-amplitude surface waves. The integral solutions are derived with the aid of the Laplace–Fourier integral transform for the dynamic response. For the case of an oscillating source, the steady-state problem is considered while for the case of an instantaneous source, the transient effect is studied. The Cauchy residue theorem is used to simplify the triple spatial integral. Then the velocity potential and the change of the sound pressure are numerically calculated. The temporal evolution and spatial distribution of the waveform of hydroacoustic sound pressure conform to the real physical situation. The hydroacoustic waves propagate at the speed of sound in the waveguide formed by the ice cover and the fluid layer. The sound pressure is sinusoidally distributed along the water depth direction and reaches a maximum value near the seabed. As the frequency increases, the sound pressure decays more slowly in the horizontal direction and also reaches a maximum value at the bottom with a greater amplitude. It can be seen that the hydroacoustic wave with a higher frequency propagates farther near the seabed and is more easily detected.

Keywords: Hydroacoustic wave, compressible inviscid fluid, Green function.

Acknowledgements

Support from the National Natural Science Foundation of China under Grant number 12272215 is gratefully acknowledged.

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A high-order shock-capturing DG method based on the TENO scheme

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Abstract: In this paper, we present a novel troubled cell indicator and limiter for the Runge-Kutta discontinuous Galerkin (RKDG) methods, based on the targeted essentially non-oscillatory (TENO) scheme [1]. Our new troubled cell indicator is inspired by the discontinuity indicator proposed in [2], but with the added benefit of being compact and specifically tailored for RKDG methods. We also propose a new limiter based on the TENO scheme, using the Hermite weighted essentially non-oscillatory (HWENO) limiter and TENO selection strategy. Unlike the TVB limiter, which requires different parameters for different cases, our new troubled cell indicator uses a uniform parameter across all cases. Moreover, our accuracy tests demonstrate that our troubled cell indicator accurately identifies regions of non-smoothness without mistaking critical points as troubled cells, resulting in better performance overall. Finally, we present a series of benchmark cases, including one-dimensional and two-dimensional cases to demonstrate the performance of our novel troubled cell indicator and limiter. Our new limiter outperforms the HWENO scheme when used in conjunction with our new troubled cell indicator.

Acknowledgements

Lin Fu acknowledges the fund from National Key R&D Program of China (No. 2022YFA1004500) and the fund from Research Grants Council (RGC) of the Government of Hong Kong Special Administrative Region (HKSAR) with RGC/ECS Project (No. 26200222).

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Forecasting of ocean wave height using a multi-recurrent neural network structure

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Abstract: Ocean wave height is an important parameter for port construction, offshore operation and coastal disaster assessment. It is very important for the development of ocean engineering to realize stable long - term wave height prediction. At present, the main method of wave height prediction is using multi-feature neural network. However, traditional neural networks are designed according to the characteristics of time series, without considering the effects of multiple physical variables on wave height.

This paper considers ocean wave height forecasts using a new multiple recurrent neural network (RNN) model. The multi-RNN model divides the input into two dimensions: the time characteristics of the predicted target and the physical characteristics that affect the predicted target. The feature extraction of two dimensions is carried out independently, and a feature gate is proposed for information fusion. We choose XMD sites along the east coast of China as the study area of this paper. The experiment was designed to predict the wave height for 3-h, 6-h, and 12-h lead times using LSTM model and multi-RNN model. the experimental results show that based on the same evaluation criteria, the performance of the multi-RNN model is better than that of the LSTM model, especially in the 12-hour lead time wave height forecast.

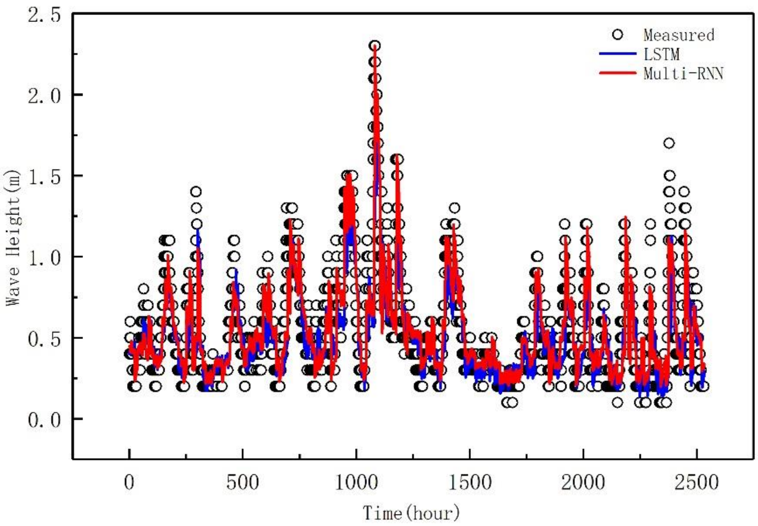

Figure 1. 12-h lead time wave height forecasting at the XMD site.

Numerical simulation of fluid-solid interactions by Peridynamics

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Abstract: This paper presents a new peridynamics approach for simulation of fluid-solid interaction problems. The classical total-Lagrangian peridynamics formulation is employed to simulate the solid. A semi-Lagrangian peridynamics (Bergel and Li, 2016) is proposed to model fluid which can flexibly consider different fluids based on reformulation of Navier-Stokes equations and equations of state (Zhu and Zhao, 2021). A coupling algorithm is developed to calculate the bond force between fluid and solid particles while avoiding unphysical penetration. The proposed computational scheme is validated through the simulation of a classic dam break problem. The predictive capability of the proposed peridynamics approach is further demonstrated by simulation of other examples including hydraulic fracturing and carbon sequestration.

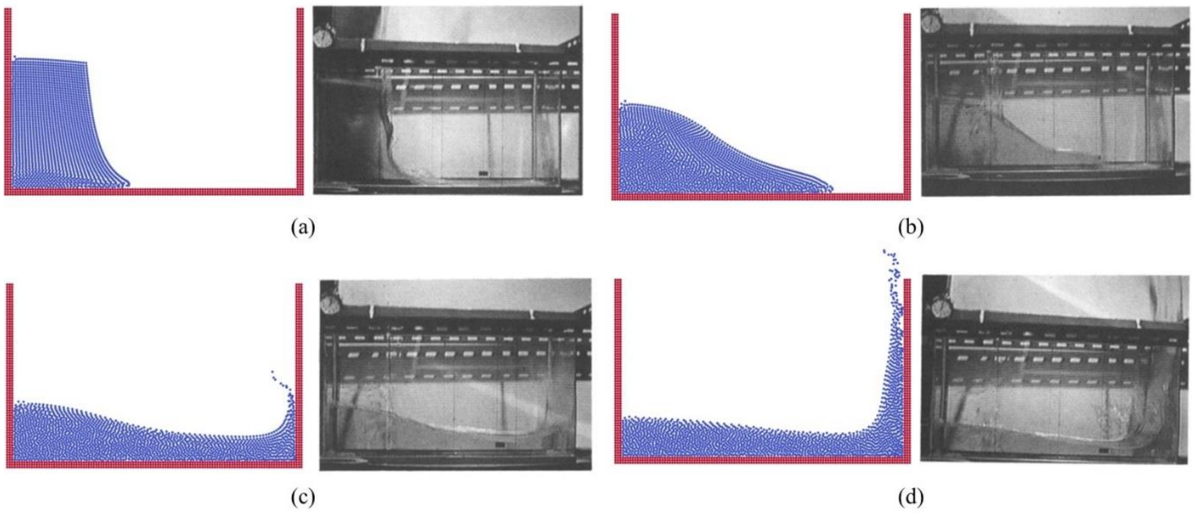

Figure 1. Comparisons between experimental results (Koshizuka and Oka, 1996) and coupled peridynamics simulation at: (a) $t = 0.1$s; (b) $t = 0.2$s; (c) $t = 0.3$s and (d) $t = 0.4$s.

Acknowledgement: The study was financially supported by RGC/GRF 16208720.

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A high-order diffuse interface method with TENO-THINC scheme for compressible multiphase flows

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Abstract: High-fidelity numerical simulation of compressible multi-phase flows is of great challenge due to its competing requirements for resolving complex flow structures with low dissipation and capturing moving interfaces as well as other discontinuities sharply. Recently, a novel hybrid scheme, utilizing the standard targeted essentially non-oscillatory (TENO) scheme and tangent of hyperbola for INterface capturing (THINC) reconstruction as two building blocks for smooth and non-smooth regions respectively and thus named TENO-THINC [1], has been proposed and shows great low-dissipation property. In this work, a high-order finite-volume method, based on the TENO-THINC scheme, is implemented on a reduced five-equation formulation of the diffuse interface model. Numerical results of these benchmark tests show that the TENO-THINC scheme is more robust than the standard TENO scheme and less dissipative than both the TENO and WENO-JS schemes.

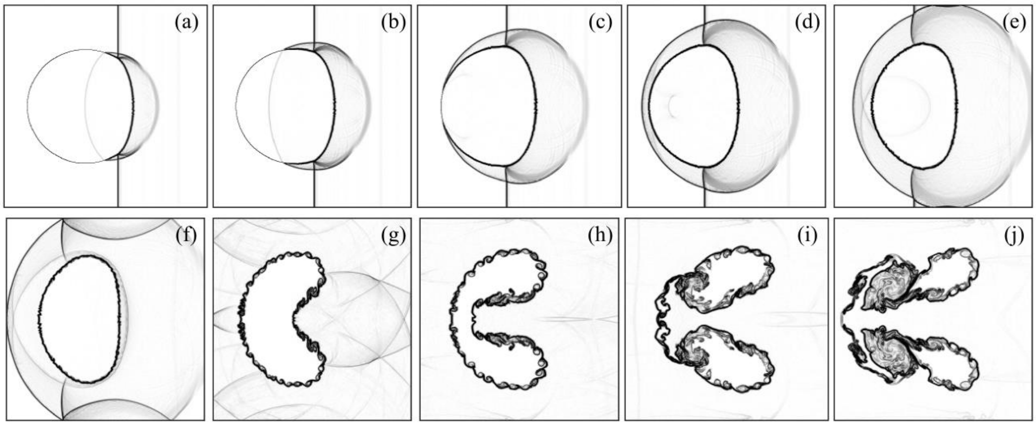

Figure 1. Schlieren images of density fields for the Helium-air shock-bubble interaction problem at the time instants (a)26,(b)37,(c)52,(d)62,(e)80,(f)102,(g)245,(h)427,(i)674 and (j)983μs, solved by TENO-THINC scheme on a 2000 × 500 uniform grid.

Acknowledgements

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Interscale transfer mechanism of turbulent kinetic energy and Reynolds shear stresses in homogeneous shear turbulence

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Abstract: The interscale transfer of energy and Reynolds shear stress in homogeneous shear turbulence is crucial to understand turbulence in fluid dynamics. In this work, homogeneous shear turbulence is studied using direct numerical simulation (DNS). By applying bandpass filtering technique, the inter-scale transfer of energy and Reynolds shear stresses are investigated. Our results show the emergence of scale-locality for both interscale transfer of energy and Reynolds stress in homogeneous shear turbulence. In specific, the eddies of a length scale l mostly transfer their energy to eddies of scale 0.3l, and that most of the Reynolds stress transfer flux goes from eddies of size l to 0.4l. It is also shown that the stretching by mean shear contributes to the production of enstrophy at large scales while the stretching by the large-scale strain rate contributes to the production at small scales. These results contribute to a deeper understanding of turbulence behaviour and have potential implications for a range of engineering and scientific applications.

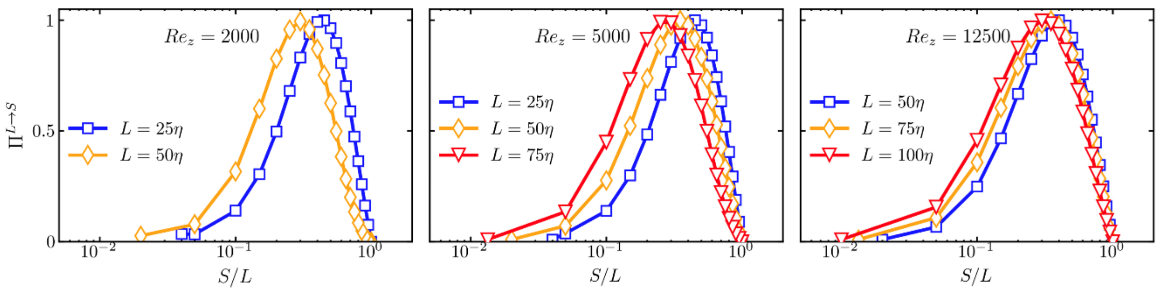

Figure 1. Normalized energy transfer flux from scale L to S versus S/L at different Re_z.

Acknowledgements

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Linear response analysis of compressible turbulent channel flows

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Abstract: Understanding and modelling high-speed turbulent flows are of fundamental importance in aerodynamic applications. In this work, the linear responses of turbulent mean flow to both harmonic and stochastic forcing are investigated for supersonic channel flow. Well-established universal relations are utilized to efficiently obtain the mean profiles with a large parameter space, so a systematic parameter study is feasible. The most amplified structure takes the form of streamwise velocity and temperature streaks optimally forced by the streamwise vortices. The outer peak of the pre-multiplied energy amplification corresponds to the large-scale motion, whose spanwise wavelength is very insensitive to compressibility effects. In contrast, the classic inner peak representing small-scale near-wall motions disappears for the stochastic response with increasing Mach number. Meanwhile, the small-scale motions become much less coherent. The geometrical self-similarity of the response in the mid-spanwise-wavelength range is still roughly satisfied, insensitive to Mach number. Finally, theoretical analyses of the perturbation equations are presented to help understand the scaling of energy amplification.

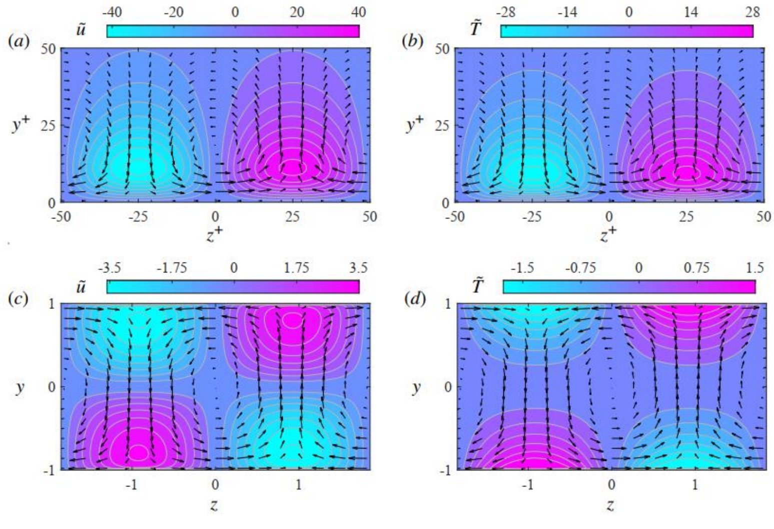

Figure 1. Contours of the (*a*, *c*) streamwise velocity and (*b*, *d*) temperature of the optimal harmonic response for the modes of the (*a*, *b*) inner peak ($\lambda_z^+ = 100$) and (*c*, *d*) outer peak ($\lambda_z = 3.7h$) in the y-z plane. The velocity vector is based on the spanwise and wall-normal velocities of the forcing.

Acknowledgements

This research was supported by the Center for Ocean Research in Hong Kong and Macau, a joint research center between QNLM and HKUST. L.F. acknowledges the fund from the Research Grants Council (RGC) of the Government of Hong Kong Special Administrative Region (HKSAR) with RGC/ECS Project (No. 26200222).

Deep reinforcement learning guided transverse force reduction for a bluff body in wake flow

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Abstract: Recently, machine learning (ML) has achieved significant development in active flow control field [1]. In this study, we develop an active flow control strategy using deep reinforcement learning (DRL) for the transverse force reduction of a circular cylinder in an unsteady wake of an upstream circular cylinder. The actuation is achieved by the self-rotation of the cylinder, and its rotation velocity is intelligently controlled by a DRL agent based on the feedback state signals from the sensors placed downstream. The environment is simulated by high-fidelity CFD using a GPU-accelerated Lattice Boltzmann Equation solver with multi-block mesh partition. Results indicate that the agent can learn from the elaborate time-series of the sensors, actuator, and rewards through trial and error, and finally converge to the optimal-control strategy within 800 episodes (see Fig.1a). The learnt control strategy can reduce 95% of the lift fluctuation for the downstream cylinder, as indicated in Fig.1(b). The policy is further verified at different Reynolds numbers and tandem distances between the two cylinders. Both show that the control strategy still works well and can effectively suppress around 90% of fluctuation of lift force. Detail wake structures are also analysed to uncover the working mechanism of this control strategy. In our talk, more analysis results will be revealed.

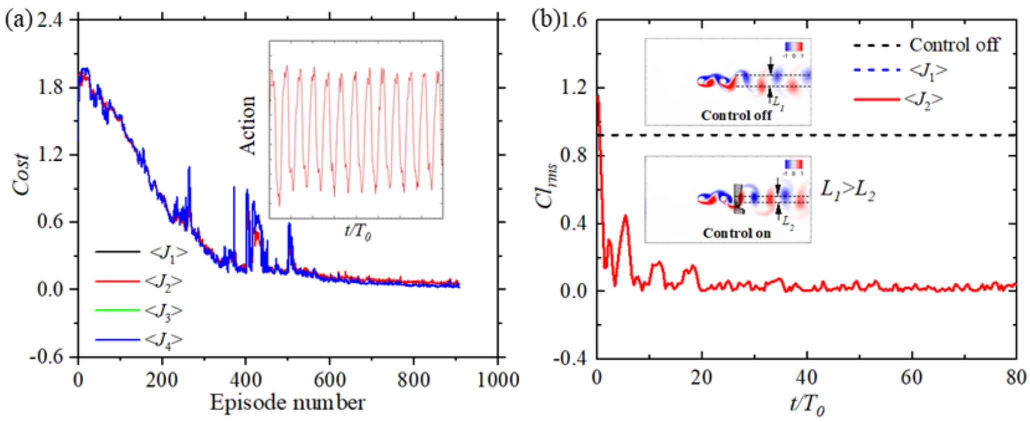

Figure 1. (a) Learning curves of DRL-trained active flow control of downstream rotation cylinder (b) comparison of rms lift force Cl_{rms} between the controlled case and uncontrolled case.

Acknowledgements

The authors wish to acknowledge the financial support by Natural Science Foundation of Guangdong Province (Project No. 2021A1515010337) and the Research Grants Council of Hong Kong under General Research Fund (Project No. 15218421).

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Impinging Core-Shell Compound Droplets on Superamphiphobic Surfaces

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Abstract: Recently, increasing interest has been shown in the impact of compound droplets due to its various applications and academic significance. However, the study of compound droplets is largely focused on their spreading stages or the impact on hydrophilic and weak hydrophobic surfaces. Here, we perform an experimental investigation on the impact of oil-in-water compound droplets on superamphiphobic surfaces. Compound droplets with different oil volumetric ratios were produced, aiming to reveal the effect of the oil volumetric ratio on the whole impact dynamics including the impact phenomena, quantitative spreading, pinning, and retraction processes. The oil volumetric ratio shows dramatic influence on the impact phenomena: the damping of the capillary wave is enhanced, the bubble entrapment can be suppressed, and water entrapment inside the oil core can be observed in a certain Weber number range. It is found that the spreading process of the compound droplet is mainly determined by the Weber number and the additional oil-water interface has no obvious effect within the scope of our research. However, the oil core can accelerate the retraction process, which reduces the contact time.

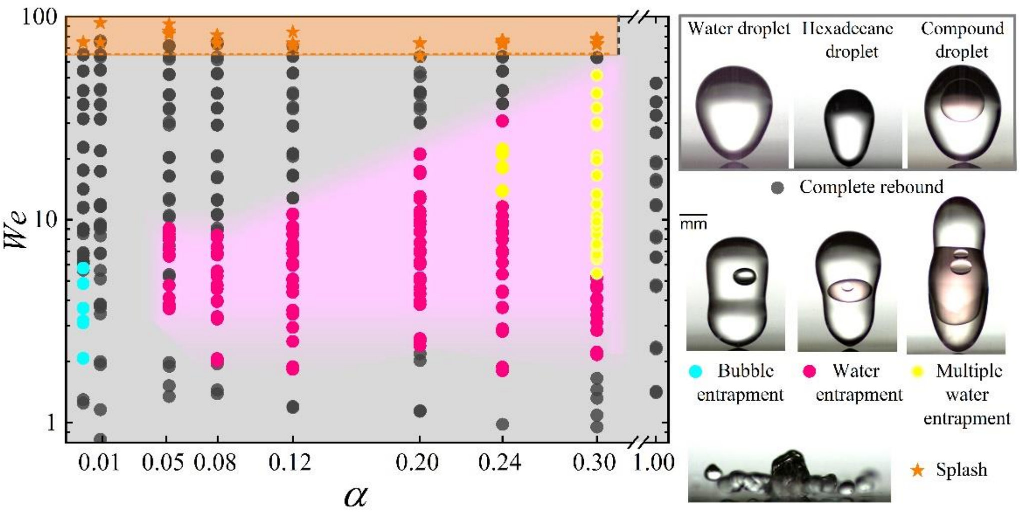

Figure 1. Impact phase diagram as a function of the Weber number and the oil volumetric ratio.

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Resolvent analysis of turbulent pipe, channel and boundary layer flows

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Abstract: Understanding the properties of coherent structures in wall-bounded turbulent flows is of great importance, as these structures are critical in determining the skin friction drag in the design of modern aircraft and ships [1]. In recent years, resolvent analysis has emerged as a powerful tool for identifying coherent structures in a variety of flows. Resolvent analysis involves linearizing the Navier-Stokes equations around the mean flow and analyzing them from an input-output perspective. The input to the analysis consists of nonlinear perturbation terms, which act as an intrinsic forcing to the linear resolvent operator. The output is the perturbation velocity field [2]. In this research, we will use resolvent analysis to determine the extent or existence of similarities between fully developed turbulent pipes and channels, and zero-pressure-gradient turbulent boundary layers. Furthermore, we aim to reveal the structural differences between these canonical wall-bounded shear flows.

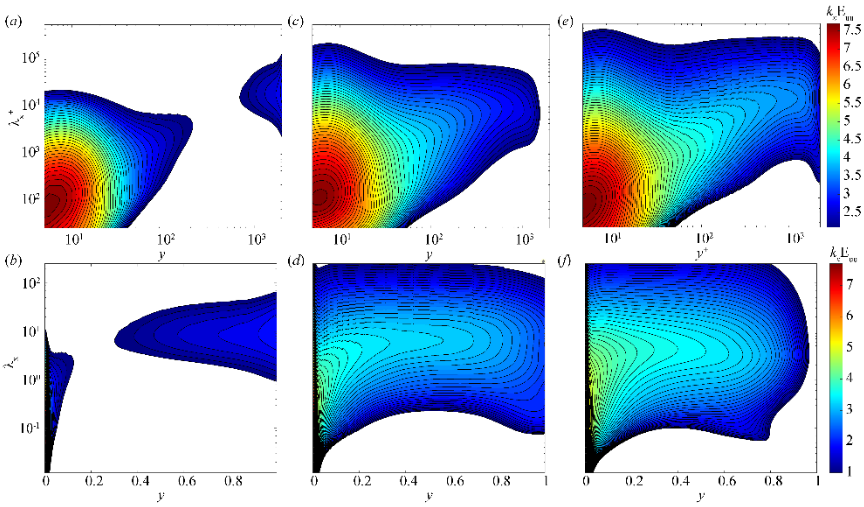

Figure 1. Premultiplied energy spectra of streamwise velocity: (*a*, *b*) turbulent boundary layer, Re_τ=1990, (*c*, *d*) channel, Re_τ=2000 and (*e*, *f*) pipe, Re_τ=2000.

Acknowledgements

L.F. acknowledges the fund from the Research Grants Council (RGC) of the Government of Hong Kong Special Administrative Region (HKSAR) with RGC/ECS Project (No. 26200222).

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Numerical simulation of discontinuous suspended ceiling systems under earthquakes

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Abstract: The discontinuous suspended ceiling (SC) system is widely used in buildings, which was reported to be easily damaged during moderate or strong earthquakes. The damage to ceilings may lead to enormous economic loss, the interruption of building function, and even threaten life safety. The study of the seismic performance of SCs is of great significance for mitigating earthquake disaster. Numerical simulation is a convenient and low-cost method to study the seismic performance of the SC. The two-dimensional numerical models for the SC have been proposed to predict the ceiling dynamic responses, while the effect of spatial effect in large ceilings could not be considered (Jiang et al., 2022). There are still some deficiencies existing in current three-dimensional finite element models proposed for the SC system. For example, the damage process of the ceiling was successfully simulated by a sophisticated finite element model by using ABAQUS software, but the accuracy of the nonlinear behavior of grid connections was not verified by test results (Gopagani et al., 2023). This study aims to provide an improved numerical modeling method for the discontinuous SC system with commonly used boundary condition. The nonlinear behavior of the peripheral connections and grid connections is considered. The uplift of ceiling panels in the vertical direction is also simulated. The failed elements exceeding their maximum deformation capacity can be timely deleted with the help of the developed removal algorithm. Nonlinear time history analysis of the ceiling under the earthquake is conducted. The responses of acceleration and displacement, and damage status are evaluated. It is found that the SC with free boundary condition generally responds as a whole in horizontal directions while the SC with boundary constraints does not vibrate as a whole with larger responses at the middle span than other locations. Comparatively, the latter has better seismic performance than the former. For both types of ceilings, the main-cross tee connections close to the ceiling perimeter are most vulnerable to earthquakes. The numerical simulation results agree well with the corresponding shaking table test results, indicating that the proposed models can be used to predict the seismic responses of the SC systems. The outcome of this study provides valuable tools for evaluating the seismic performance of discontinuous SC systems.

Acknowledgements

The financial support from National Key Research and Development Program of China under Grant No. 2022YFC3803003 is gratefully acknowledged.

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Numerical study of the stability of the rock armor layer under extreme wave erosion using the resolved CFD-DEM method

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Abstract: Rock armor layers have been widely used to defend the wave erosion on coastal structures, such as breakwaters, embankments, and reclaimed islands. With more occurrence rate of extreme waves, climate change increases the failure risk of existing coastal armor layers. We propose a numerical model to simulate the interaction of waves and rock armors by resolved CFD-DEM method. The wave motion is calculated by the computational fluid dynamics (CFD) method, and the motion of armor units is simulated by the Discrete Element Method (DEM). The interaction between the wave and armor unit is calculated by a resolved coupling approach. We simulate the periodical wave impact on rock armor layers. Two types of armor unit shapes are studied, the cuboid and dolos rock shapes. The relationship between the armor unit shape, weight, and armor layer stability is discussed. The results show that the dolos shape can increase the interlocking between armor units and reduce the required unit weight to achieve equivalent stability compared with the cuboid shape. A lighter dolos armor unit increase of risk of rocking and breakage compared with the heavier cuboid armor unit. This numerical method can calculate the wave energy dissipation of complexly shaped rocks and estimate the stability of rock armor layers under extreme wave loading.

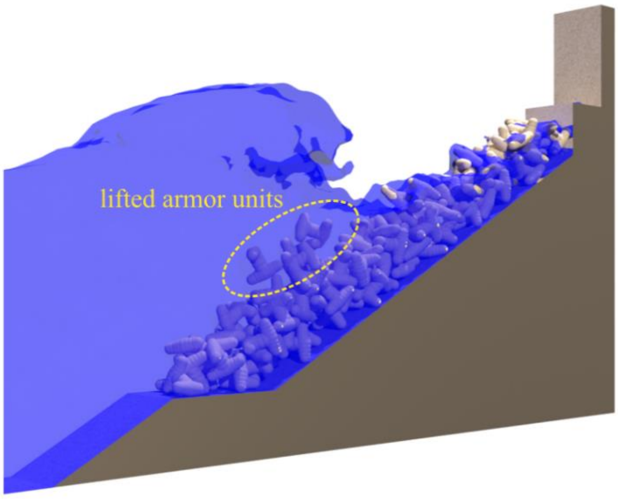

Fig. 1 The motion of dolos armor units under the extreme wave attack

Acknowledgements

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Some New Insights into Rainfall-induced Flowslides of Granular Soils

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Abstract: Rainfall-induced flowslides in earthen slopes present one of the most destructive natural hazards. Such hazard mitigation requires a good understanding of soil behavior under the constant shear drained (CSD) stress path, which is more pertinent than typical triaxial tests to soil element under rainfall infiltration. Here we explore various behaviors of loose granular packings along different stress paths and the associated micromechanical mechanisms using a robust grain-scale modeling technique. Through systematic simulations of the CSD, constant-volume (CDCV), and conventional drained (CD) shearing stress paths, we find that the behavior under the CSD stress path conforms to critical state concepts at both macro- and micro-scale. The evolution of the stress ratio (q/p') along the CSD stress path is highly similar to that along the CD stress path. A substantial plastic strain tends to develop once the second-order work becomes nonpositive along the CSD stress path, while a dramatic drop of shear strength will occur at the vanishing of second-order work along the CDCV stress path. In both cases, the second-order work vanishes at an almost identical stress ratio, which demarcates the lower boundary of the potential instability zone. Furthermore, we establish an explicit relationship between this stress ratio and the initial state parameter of the packing.

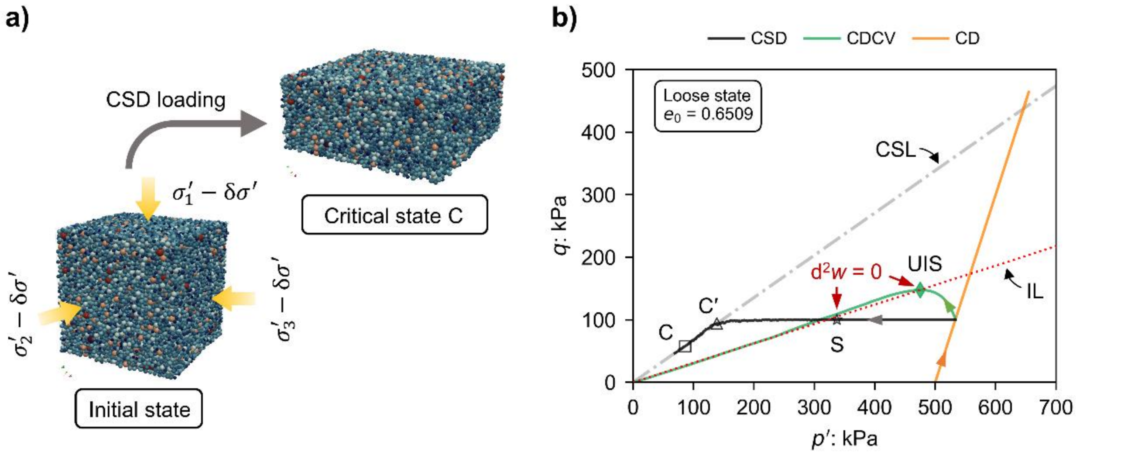

Figure 1. (a) Configuration of the representative volume element at the initial state and critical state in CSD simulation; (b) Stress paths of CSD, CDCV, and CD tests

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Study on penetration behaviors of foam into saturated sand in EPB tunneling

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Abstract: Foam is a commonly used soil conditioner in EPB shield tunneling to temporarily modify soil properties and maintain the workability of the EPB shield. Previous studies have shown that injecting foam at the tunnel face using soil conditioning tools expels pore water from the soil and hence alters the properties of excavated spoil. Moreover, with the foam penetrating the sand on the tunnel face, a low permeable layer will be formed that benefits in transferring the support pressure to the soil skeleton. Therefore, it is essential to study foam penetration behaviors into saturated sand under pressurized conditions. This study presents the results of an experimental investigation into the penetration behavior of foam into saturated sands at the macroscopic level. A series of foam penetration tests were conducted using a cylindrical model test setup. The results show that the hydraulic conductivity of sand columns decreased from approximately 10-1 cm/s when saturated with water to values ranging from 10-2 to 10-5 cm/s when penetrated with foam. Additionally, the rheological properties of the foam were measured using a rheometer, and the results were modeled using the power-law model for non-Newtonian fluids. The correlation between the seepage velocity of the foam and the hydraulic gradient on the foam-penetrated sand column was deduced based on the power-law fluid model. The findings reported in this study provide a basis for elucidating the mechanism of foam as a soil conditioner from an anti-permeability perspective in tunnel excavation.

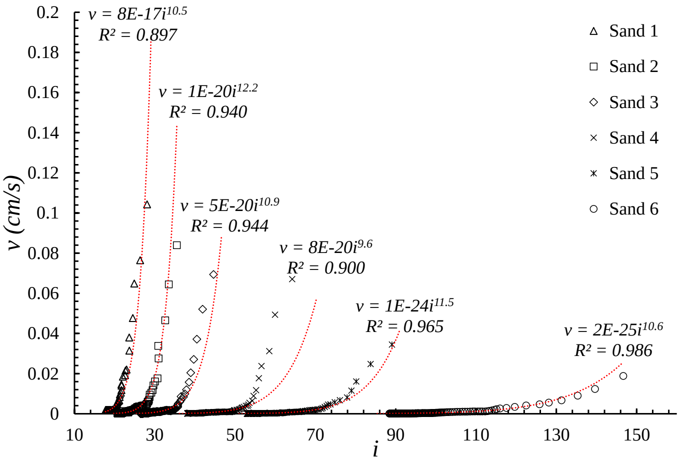

Figure 1. Variation of foam seepage velocity with the hydraulic gradient in different sand.

Acknowledgements

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An Explicit-Implicit THM-Coupled MPM for Saturated Porous Media

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Abstract: The thermal-hydro-mechanical (THM) responses of porous media underpin the operation and performance of key engineering applications. In this study, we introduce a coupled material point method (MPM) to model the THM behaviour of saturated soils. The governing equations are presented using the u-v-p-T formulation adaptable for dynamic and large deformation problems. An effective explicit-implicit solution scheme is further developed wherein the pressure is solved using the operator-splitting method to avoid the constraint of liquid compressibility. The proposed method is validated by simulation of a three-dimensional axisymmetric benchmark scenario involving the thermoelastic response around a point heat source. We further demonstrate the proposed method by simulating the large deformation and progressive failure in a slope caused by thermal softening. The results indicate that the presented method has the potential to simulate climate-change-driven soil degradation and related problems, such as thawing permafrost.

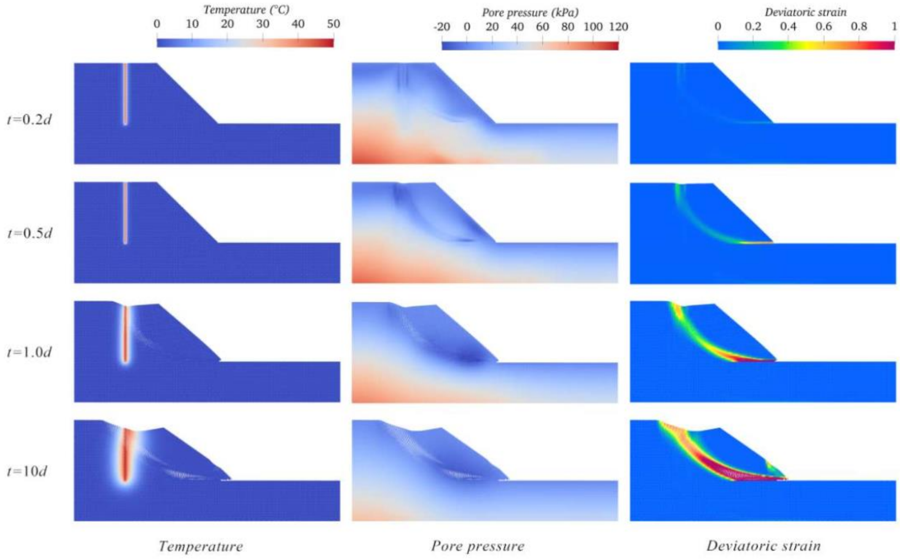

Figure 1. Simulation results of temperature, pore pressure, and deviatoric strain in a saturated soil slope undergoing large deformation and progressive failure due to thermal softening.

Acknowledgement: The study was financially supported by RGC/GRF 16211221.

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In-situ Mechanical Calibration for Vision-based Tactile Sensors

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Abstract: This paper proposes a novel approach to conduct routine calibration for the changing mechanical parameters over time of a vision-based tactile sensor without disassembling its overall structure, i.e., in-situ mechanical calibration. Calibration for mechanical parameters, Young's modulus and Poisson's ratio, of a tactile sensor's sensing elastomer is vital for its force perception capability. However, there are few methods that can retrieve values of these parameters both accurately and conveniently. To address this problem, we propose an in-situ approach to calibrate mechanical parameters other than the verbose traditional evaluation process. This method incorporates the deformation sensing capability of the sensor, the accurate force sensing capability of a force/torque sensor, and most importantly, the deformation-force relationship for an indentation with the elastomers' mechanical parameters encoded. We propose the indentation test setup and the pipeline to extract Young's modulus and Poisson's ratio from experimental results. We validate the method by comparing the FEA simulated indentation depth using the calibrated parameters with the indentation depth measured in real experiment. Furthermore, superior contact force distribution can be achieved with the accurate mechanical parameters. The proposed method presents the theoretical basis that enables accurate lifelong routine calibration, weekly or even daily, which can promote the applications of tactile sensors in real manipulation scenarios.

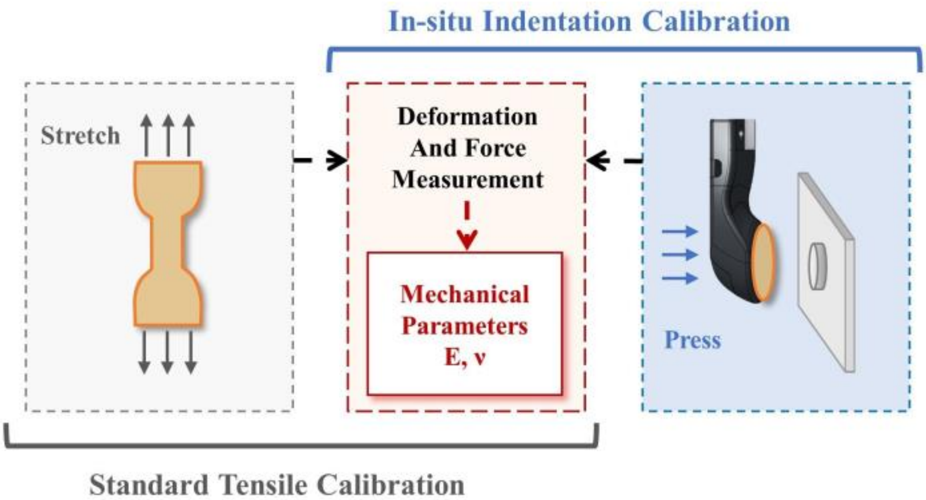

Figure 1. A sample of a figure (the caption is in Times New Roman 10 pt).

Acknowledgements

The authors wish to thank Dr. Chen Sun for his generous help in conducting experiments.

Method, Approach, Treatment and Solution for Classical Elasticity in Layered Solids

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Abstract: The mathematical theory of linear elasticity is one of the most classical field theories in mechanics and physics. It was developed and established by many well-known scientists and mathematicians over 200 years from 1638 to 1838. For more than 185 years from 1838 to present, the key task in classical elasticity has been the mathematical, analytical and/or numerical derivation and formulation of solutions for boundary value problems of interesting in science and engineering. Many well-known scientists and mathematicians have made tremendous efforts in mathematically and analytically derive and formulate solutions for some classical problems. However, the solutions and/or fundamental singular solutions in closed form are very limited in literature. The boundary-value problems of classical elasticity in layered and graded solids are also one of the classical problems, which were not well solved. Since 1984, the author has examined the solutions of the classical problems using the classical mathematical tools such as Fourier integral transforms and matrices. This paper presents on the development history, the main findings, and the fundamental singular solutions for elasticity of either isotropic or transversely isotropic layered solids subject to concentrated loadings. Their singularities are isolated and integrated analytically in exact closed-forms in terms of elementary harmonic functions and special functions. As a result, the solutions in layered or graded solids can be calculated with any controlled accuracy in association with classical numerical integration techniques. The mathematical procedures and solutions have been named by other researchers as Yue's approach, Yue's treatment, Yue's method and Yue's solution. The mathematical approach, treatment and method have also been applied to systematically derive and formulate new solutions in elastodynamics, poroelasticity and thermoelasticity and with boundary element methods.

Acknowledgements

The author thanks many people for their supports and/or advices on this study project over the past 40 years.

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Distribution of ripples in graphene membranes

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Abstract: Intrinsic ripples with various configurations and sizes were reported to affect the physical and chemical properties of two-dimensional (2D) materials. By performing molecular dynamics simulations and theoretical analysis, we use two geometric models of the ripple shape to explore numerically the distribution of ripples in the graphene membrane. We focus on the ratio of the ripple height to its diameter (t/D) which was recently shown to be the most relevant for chemical activity of graphene membranes. Our result demonstrates that the ripple density decreases as the coefficient t/D increases, in qualitative agreement with the Boltzmann distribution derived analytically from the bending energy of the membrane. Our theoretical paper provides also specific quantitative information on the ripple distribution in graphene and gives new insights applicable to other 2D materials.

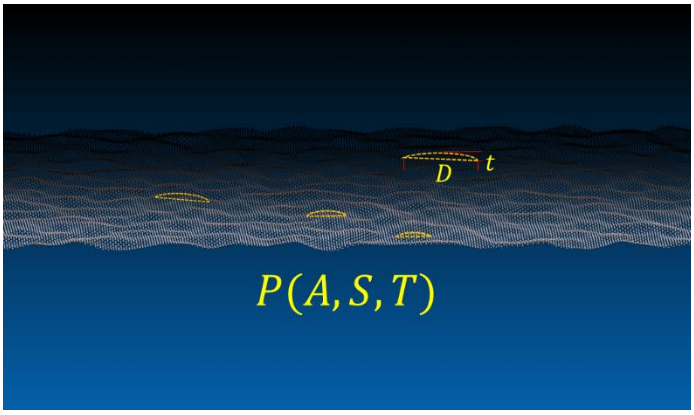

Figure 1. Snapshot of graphene membrane at 300 K by molecular dynamics simulations.

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Hydrogen-enhanced separation distance of two partials of edge dislocation in nickel

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Abstract: Hydrogen embrittlement is an important technological problem underpinning failure of many structural elements. It has been extensively investigated in the literatures; however, several open issues remain that prevent a full understanding of this phenomenon. One important issue is the uncertain knowledge of how hydrogen atoms affect the dislocation core structure. Here, by exploring the hydrogen role on the dissociated edge dislocation, we reveal that there exists an additional attractive force between two partials due to the hydrogen atmosphere, which would reduce the equilibrium separation distance. This hydrogen-induced attractive force is quantitatively estimated by means of continuum mechanics. Furthermore, molecular statics simulations also capture the hydrogen-reduced separation distance under varying hydrogen background fractions, qualitatively verifying the theoretical prediction of attractive force. These findings at the atomistic scale will inform the hydrogen embrittlement modelling and experiments, especially on the hydrogen effect on the dislocation glide, climb, dynamics strain aging, and so on.

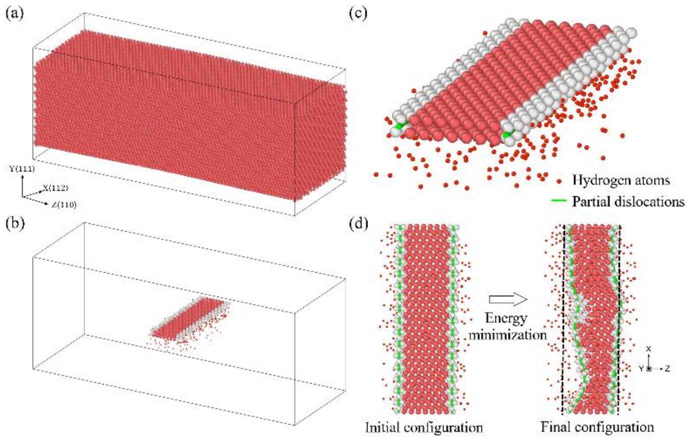

Figure 1. Hydrogen-enhanced separation distance of two partials.

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A local to global (L2G) finite element method for efficient and robust analysis of arbitrary cracking in 2D solids

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Abstract: This paper presents and validates a new local to global (L2G) FEM approach that can analyze multiple, interactive fracture processes in 2D solids with improved numerical efficiency and robustness. The method features: 1) forming local problems for individual and interactive cracks; and 2) parallel solving local problems and returning local solutions as part of the trial solution for global iteration. It has been demonstrated analytically (through a simple 1D problem) and numerically (through several benchmarking examples) that, the proposed method can substantially improve the robustness of the global solution process and significantly reduce the costly global iteration for convergence. The demonstrated improvement in numerical efficiency is up to 20 ~ 40% for mildly unstable problems. For problems with severely unstable crack initiation and propagation, the improvement can be more significant. This new method is readily applicable to other popular methods such as the extended FEM (X-FEM), Augmented FEM (A-FEM) and Phantom-node method (PNM).

Acknowledgements

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Application of high formwork support system safety monitoring based on fiber Bragg grating sensors

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Abstract: The application of fiber Bragg grating sensors for safety monitoring of high formwork support system (hereinafter referred to as “high formwork”) when mass concrete is poured is described. Combined with actual engineering cases of Galaxy Macau Phase 4 Transfer Plate, the fiber Bragg grating sensors are used to monitor the box settlement, horizontal displacement of support system, axial force, and concrete temperature change. All the fiber Bragg grating sensors are specially designed for the measured parameters. And the installation method of the related sensors and the solution to the temperature strain cross-sensitivity of the fiber Bragg grating sensors are also described. This paper explores the advantages and disadvantages of fiber Bragg grating sensors for safety monitoring of high formwork support systems and provides reference for subsequent safety monitoring of similar projects.

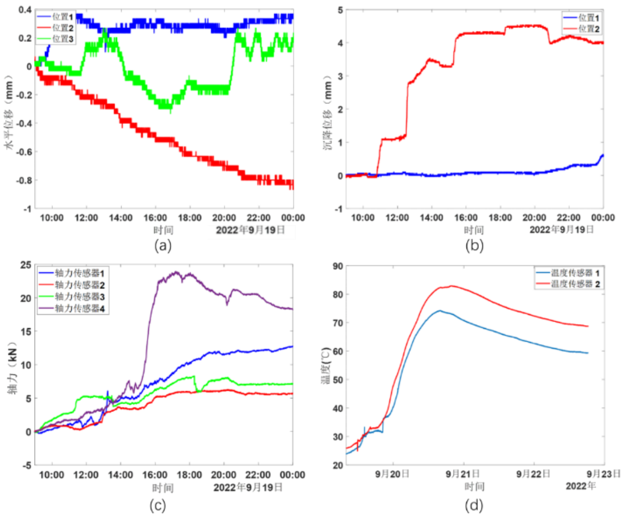

Figure 1. The real-time monitoring result.

Acknowledgements

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Shape Selection of Pre-shaped Liquid Crystal Elastomer Strips

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Abstract: Liquid crystal elastomers (LCEs) are slightly crosslinked liquid crystalline polymer networks. LCEs combine three important ideas: orientational order in amorphous soft materials, responsive molecular shape, and quenched topological constraints [1]. Together, they create many new physical phenomena and lead to various applications, including but not limited to photonic devices, soft robotics, artificial muscle, and metamaterials. Recent research have revealed that chirality plays a critical role in controlling the shape of self-assembled supramolecular aggregates. A range of chiral shapes, including tubes with spiral ribbons (with cylindrical curvature and helical central line), and helicoids (with Gaussian saddle-like curvature and straight central line), have been observed in various biological materials and their synthetic analogues. The correlation between material characteristics and the macroscopic shape of chiral aggregates is markedly complicated and hasn't been fully explored. A flat twist-nematic-elastomer (TNE) film can select between helicoids and spiral ribbons when subjected to temperature change [2]. To mimic the real biological systems better and facilitate applications in a broader range, we further explore the shape formation of pre-shaped and constraint LCE strips in this work. We simulate the deformation process of pre-bend and pre-twist LCE strips, and we are able to achieve a spiral ribbon shape in a narrow strip.

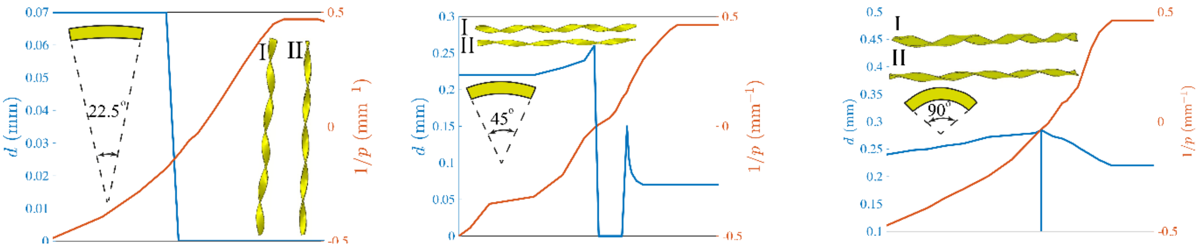

Figure 1. Shape transition with the change of pre-bend curvature (strip width: 0.2mm).

Acknowledgements

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一种基于损伤机制及热力学基本原理推导的蠕变寿命预测模型

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摘要：本工作力图在连续介质力学框架内，结合热力学基本定律与蠕变损伤机制，推导出一种预测蠕变寿命的理论模型。不同于传统的唯象损伤力学，本工作中本构方程严格遵循热力学基本定律，考虑了两种典型的蠕变损伤机制，即低应力作用下的空位扩散与高应力作用下的位错黏性滑移，能准确预测广应力范围下蠕变寿命曲线的“拐点”，解决长时蠕变寿命外推的重点与难点。理论模型成功预测了不同温度下耐热合金钢的蠕变寿命曲线，表明了本次工作在展现了科学创新的同时，也具有实际的工程应用价值。

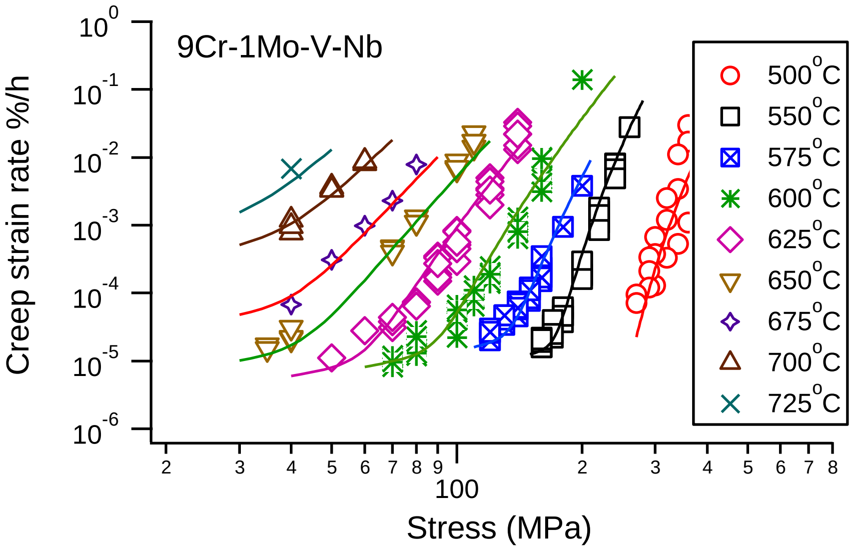

图 1. 高温耐热合金钢 9Cr-1Mo-V-Nb 的蠕变寿命曲线预测

PEM 燃料电池快速冷启动中结冰双极板的广义热弹耦合问题研究

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摘要：质子交换膜燃料电池（PEMFC）的高效率、低排放等特点使其在众多领域拥有良好的应用前景。而低温快速启动是制约 PEMFC 汽车大规模商业化的关键瓶颈技术之一。为实现更低温度、更短时间启动，基于热能除冰的 PEMFC 系统中的冰和构件不可避免地受到高速热冲击作用，导致局部发生快速升温与变形。而热流变化迟滞效应、冰材料的结构相变、基体传热与变形过程的高度耦合以及结冰构件界面处的耦合变形都大大增加了问题的分析难度。针对这个问题，本文以结冰双极板为例，基于非傅里叶导热定律构建了双极板-冰的伴相变瞬态热弹耦合模型，分析了冷启动工况下非经典传热效应以及融冰相变给温度场和应力场分布所带来的影响，以探究热冲击下极速融冰过程致 PEMFC 双极板结构破坏与功能退化的机理。结果表明，热冲击以及冰层受热膨胀引起的挤压变形会给极板结冰表面带来高水平且具有典型非傅里叶特性的拉压交变应力，极易导致材料破坏和结构受损，这对控制 PEMFC 冷启动过程中的结构可靠性造成了极大威胁。同时，相变潜热以及材料巨大的导热系数差也给双极板的快速融冰带来不利影响，在限制融冰速度的同时也导致了融冰能耗的显著增加。相应的研究结论为 PEMFC 的设计和冷启动的控制提供了理论依据。

致谢

感谢国家自然科学基金面上项目“基于域峰值泛函表征的燃料电池系统高低负载区效率提升”(52072265)的资助。

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一种热力学自洽的新型蠕变-循环塑性耦合本构模型

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摘要：本工作开展了关于高温合金的蠕变-疲劳理论研究工作，将具体蠕变变形机制与塑性理论相结合，希望在满足工程计算的需求同时赋予理论模型更为深入的物理基础。首先，本工作考虑了具体蠕变与疲劳机制，提出两者耦合的理论准则，随后将基于热力学基本定律推导相关内变量演化方程，保证理论模型的热力学基础，从而实现理论模型在物理以及热力学基础上的升华。因此，本项目的研究成果在航空航天领域应用方面，能为以 TC4 为代表的钛基合金的高温蠕变疲劳耦合行为描述以及预测提供定量的理论计算参考；在科学研究方面，能进一步拓展蠕变-疲劳耦合本构模型和损伤力学的研究，为工程计算奠定更为深刻的物理基础。

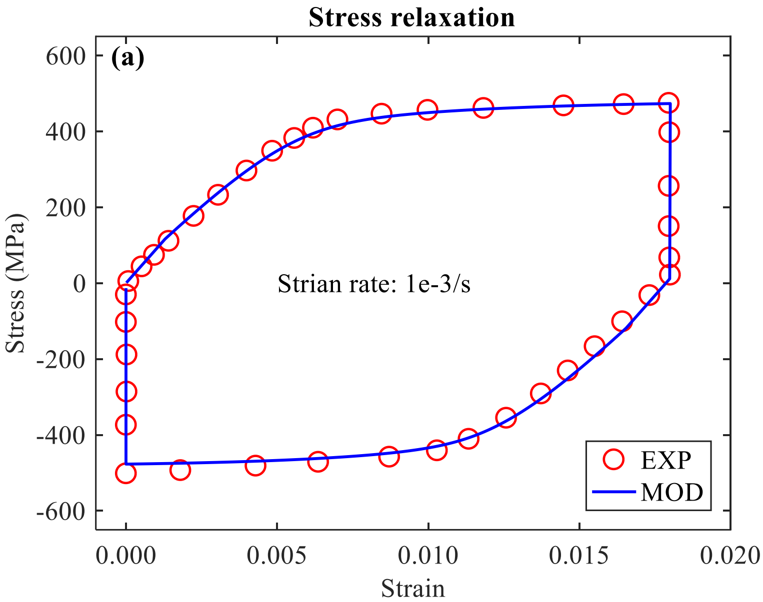

图 1. 高温 TC4 合金的蠕变-塑性耦合力学行为

Linear polymer chain diffusion in semi-flexible polymer network: A dissipative particle dynamics study

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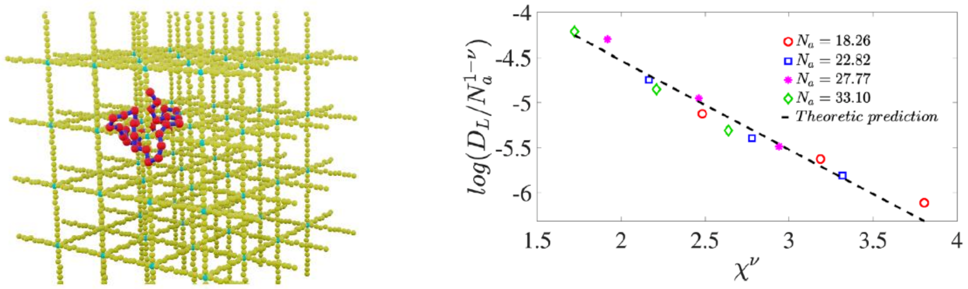
Abstract: Linear polymer chains transport in the crowded biological environment is profoundly important to biomedical engineering and nanotechnology. Cytoskeleton, which can be modelled as a semi-flexible polymer network, acts as a barrier when linear polymers diffuse inside the cell. The diffusion of linear polymers with length N in this polymer network is investigated by the dissipative particle dynamics (DPD) in the present study. Rouse theory is applied to analyse the conformational dynamics of the linear polymers based on the numerical results. It is found that the geometric constraint length Na is a crucial parameter to describe the role of the network of the polymer diffusion. Analyses on Rouse modes show that, in a short wavelength regime, the relaxation time obtained in numerical simulation follows the prediction of the Rouse theory. With the increasing wavelength, the linear polymer exhibits a transition from reputation behaviour to the spatially homogeneous behaviour at critical length scale Na, which is illustrated by different scaling laws dependent on wavelength. Based on the analyses on the Rouse modes and mean square displacements of the linear polymer, we present a non-dimensional conformational dynamic function dependent on time, with which a scaling law is proposed to predict the long-time diffusivity of the linear polymer in a semi-flexible polymer network with different mesh sizes. It is shown that the prediction is well consistent with our DPD simulation results.



(a) (b)

Figure 1. (a) Schematic diagram of the linear polymer in a semi-flexible polymer network, where the red spheres and blue lines represent the linear polymer, yellow spheres represent the monomers in the semi-flexible polymer network, and cyan spheres represent the junctions in the polymer network. (b) Comparison of long-time diffusivity D_L from theoretical prediction and numerical simulation. The dashed line represents for the prediction of theoretical model.

Mechanical force facilitates the SARS-CoV-2 viral entry

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Abstract: A global COVID-19 pandemic caused by the SARS-CoV-2 has lasted for three years since 2019. The recognition of SARS-CoV-2 spike by the human ACE2 receptors induces the spike conformational change, and eventually triggers the viral entry. Our experimental studies showed piconewton pulling forces regulate the recognition and the conformational change of spike protein. As a result, mechanical pulling facilitates the viral entry. However, the forces applied to the spike and ACE2 during the entry is yet elusive. Herein, we developed a theoretical model to quantify the forces on the spike–ACE2 bonds. According to the model, compressive forces are applied to spike¬–ACE2 bonds at the middle of the contact zone, while the bonds at the edge experiences pulling forces in a range of 0~30 pN. Together with the experimental findings, we demonstrate that mechanical force fosters SARS-CoV-2 spike recognition of ACE2 and accelerate follow-up spike conformation change.

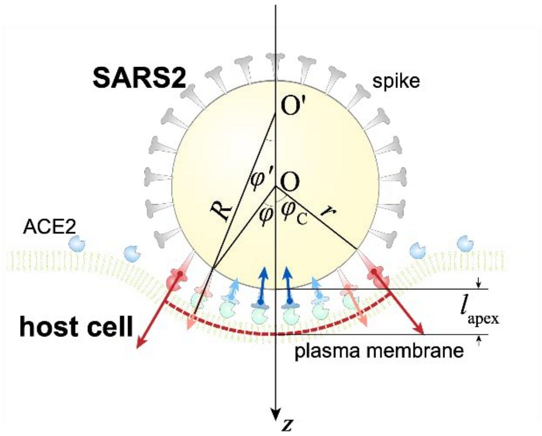

Figure 1. The model concept.

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High-performance and wide relative humidity passive evaporative cooling utilizing atmospheric water

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Abstract: The global demand for cooling systems has increased rapidly due to global warming and improved living standards. However, meeting this demand in economically underdeveloped areas is challenging due to limited access to electricity. Evaporative cooling, which utilizes the liquid-vapor phase change of water and provides high enthalpy, is a widely used and cost-effective solution. Nevertheless, its potential applications are limited by the significant amount of water required for the process. In this study, we present a high-performance and wide relative humidity (RH) solar-driven evaporative cooling strategy that uses atmospheric water exclusively. We have designed a composite material comprising a hygroscopic salt-modified metal-organic framework (MOF-801) with exceptional atmospheric water absorption capabilities across a broad range of RH. This composite material mimics the natural "breathing" process of adsorption and desorption cycles, allowing it to naturally and sustainably absorb water from the air at low temperatures and desorb it at high temperatures.

Our experiments demonstrate that the composite material can adsorb atmospheric water up to ~22% (~80%) of its weight at an RH@28% (~70%). By coating this composite material onto a commercial solar panel, we have achieved cooling powers ranging from 136 to 344 W/m2 across a broad range of RH, with passive cooling temperatures up to 14 ℃ lower than those of the device's reference counterpart. This innovative design presents a promising pathway to replace traditional compression-based cooling systems, such as air conditioners, and provides a direction for designing cooling systems that can reduce global energy consumption in the future. Our study sheds light on the potential of atmospheric water as a sustainable resource for meeting the growing demand for cooling systems, especially in underdeveloped regions.

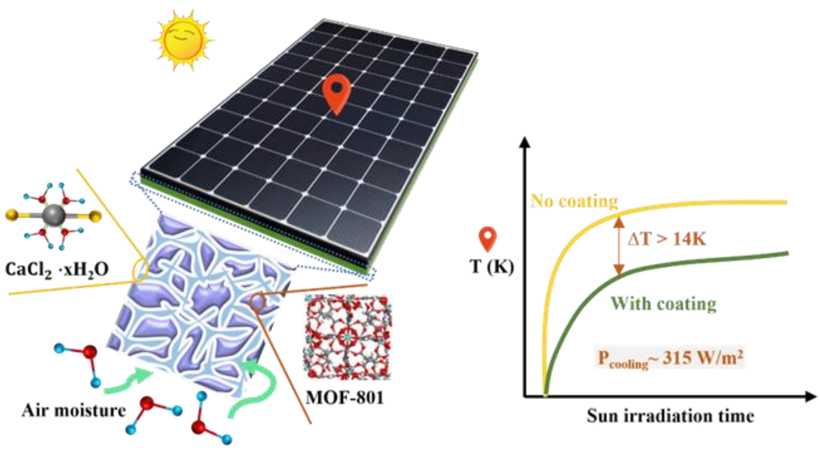

Figure 1. The evaporative cooling strategy based on hygroscopic salt and MOF composite. The cooling demonstration for commercial PV panel showed a cooling power ~315 W/m^2 with a maximum cooling temperature up to 14 K.

Acknowledgements

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A data-driven reconstruction method for dynamic systems with multistable property

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Abstract: In this work, Sparse Identification of Nonlinear Dynamics (SINDy) algorithm is generalized to nonlinear dynamic systems with multistable property. For a bistable bionic joint, we find that the classical SINDy fails for its dynamical model reconstruction due to the lacking ergodicity with tiny amount of time history signals. Aiming at the accuracy and precision of model reconstruction of multi-stable nonlinear dynamic systems, a generalized data-driven reconstruction method is proposed based on data assembly principle and sparsification parameter determination technique. The datasets are expanded by different initial conditions for the dynamics ergodic. Besides, to resolve the difficulty on the determination of sparsification parameter, the bi-objective optimization scheme considering both sparsity and accuracy of the reconstruction model is constructed. Based on the Pareto front and Knee point theory of the bi-objective optimization scheme, it provides the precisely determination technique for the sparsification parameter range. Two numerical examples are conducted on bistable and quad-stable nonlinear systems to verify the effectiveness of the generalized data-driven reconstruction method. Then, the experimental prototype of the bionic joint with bistable property is carried out, which possesses both geometric and constitutive nonlinearity. Assembling the experimental signals with measurement noise according to the proposed data assembly principle, the generalized reconstruction method proposed in this paper can capture the position of the stable equilibriums and accurately reconstruct the dynamic model of the bistable bionic joint. Since the ergodic dataset can be further extended, proposed reconstruction method for dynamic systems with multistable property has effectiveness and robustness. The generalized data-driven reconstruction method successfully solves the problems of non-ergodic data and undetermined sparsification parameter in the model reconstruction of multistable systems, which could be further extended to reconstruct the governing equations of nonlinear dynamic systems with hysteresis nonlinearity. The proposed reconstruction method can be applied to the model reconstruction of multistable nonlinear systems in the fields of robotics, deployable structures etc.

Acknowledgements

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Ultralong mean free path phonons in HKUST-1 and their scattering by water adsorbates

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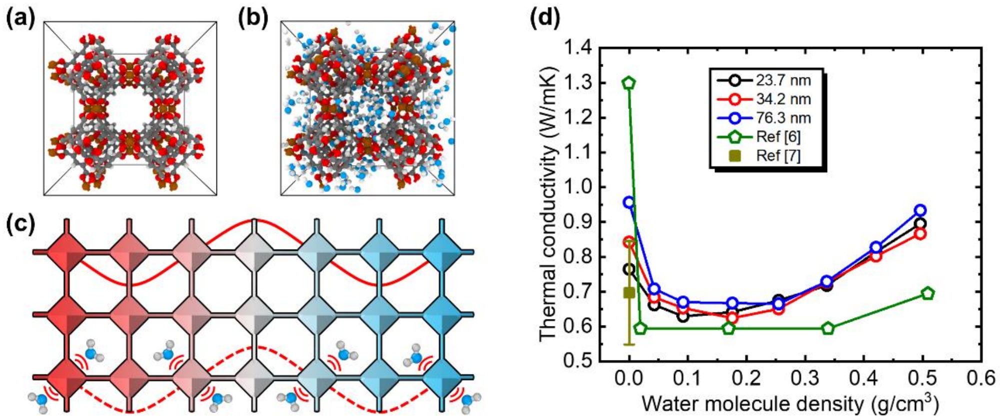
Abstract: Metal-organic frameworks (MOFs) have gained tremendous attention due to their potentials in energy areas, such as carbon capture, catalysis, chemical sensing, and gas separation and storage. Their thermal transport properties which determine their performance must be known while are rarely studied[1, 2]. Using atomistic simulations and experimental measurement[3, 4], we systematically investigate the thermal transport properties of a typical MOF (i.e., HKUST-1) considering the adsorbed water molecules.

We find that the thermal transport in HKUST-1 is significantly depressed under the impacts of water adsorbent. We computationally prove that the mean free path of these small wave vectors can exceed one hundred nanometer and the corresponding thermal conductivity is strongly size dependent. Our results reveal that the adsorption of water molecules into framework could introduce extra phonon scattering in HKUST-1. These long mean free path phonons in HKUST-1 are strongly scattered by the adsorbed water molecules resulting in the weak size dependence in the thermal conductivity of water adsorbed HKUST-1. The simulation results find that two pathways for the thermal energy exchange, e.g., the phonons and the water molecules, exist in HKUST-1 with water molecules. The competition between the two thermal pathways leads to the first decreased and then increased thermal conductivity with the quantity of the adsorbates.

Our results demonstrate that the thermal transport properties of MOFs can be modulated largely by water adsorbents, which can benefit the thermal management design of MOFs' thermal-related applications[5].



(a)

Figure 1 (a) The original structure of HKUST-1. (b) The configuration of adsorbed HKUST-1 with a water molecule density of 0.337 g/cm3. (c) Schematic illustration of the influence of water adsorption on phonon transport of HKUST-1. (d) The thermal conductivities of adsorbed HKUST-1 with different water molecule density, and thermal conductivities from Refs. [6, 7].

Acknowledgements

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Investigation of the over-tip shock waves in tip leakage flows

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Abstract: In most cases, rotor-blade tip clearance is inevitable in ducted turbomachinery to avoid blade-tip abrasion. Due to the aerodynamic loading, a pressure difference is imposed between the inlet and the exit of the clearance. This leads to pressure-driven tip leakage flows (TLFs). Time-resolved schlieren visualization is used to investigate TLFs in the clearance region. A common generic blade tip model is tested in a wind tunnel under transonic operating conditions. A multi-cutoff superposition technique is developed to achieve better flow visualization. Quantitative image processing is performed to extract details of TLFs. Unsteady flow structures such as over-tip shock oscillation, shear-layer flapping, and vortex shedding are revealed by Fourier analysis and dynamic mode decomposition. To predict the generation and decaying of over-tip shocks, a simplified model is proposed by analogizing the shock system to be an N-shaped sawtooth wave. The results show that: (1) The proposed model is able to capture the main features of the generation and decaying of over-tip shock waves. The processes of shock generation, decaying and fading-out are dominated by the mean background flow, the shock state and the flow fluctuations, respectively. Adding extra coming flow fluctuations can be an efficient way to control the evolution of over-tip shock system. (2) The over-tip shock waves are locked-in by frequency and position with the shear-layer flapping mode. This lock-in effect is also observed in TLFs over contoured blade tips. Constrained by this lock-in effect, the evolution of over-tip shock waves is separated into four discrete phases. This spatial-distribution pattern can be applied for the control of over-tip heat loading and the rolling-up of tip leakage vortices.

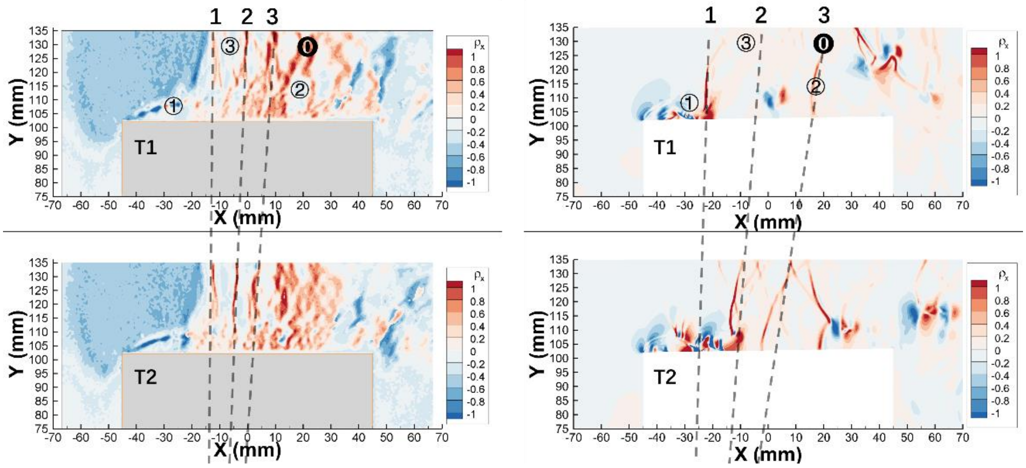

Figure 1. Time-resolved density gradient distributions: (a) measured; (b) predicted.

Acknowledgements

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Linear-model-based study of the coupling between velocity and temperature fields in compressible turbulent channel flows

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Abstract: We employ a linear model, i.e., the two-dimensional spectral linear stochastic estimation (SLSE) [1], to study this coupling from the perspective of the multi-scale energy-containing eddies. The connections of the two fields are found to be varied with the wall-normal position in the boundary layer. Their entanglement is strongest in the near-wall region, and only the extreme thermal events cannot be captured by SLSE. In the logarithmic region, only the scales that correspond to the attached eddies and the very large-scale motions (VLSMs) are firmly coupled. The near-wall footprints of the former are organized in an additive manner and fulfil the predictions of the celebrated attached-eddy model. In the outer region, the two fields are linearly coupled only at the scales corresponding to VLSMs. These findings are demonstrated to be insensitive to the Mach number effects and ascribed to the similarity between the momentum and the heat transfer in compressible wall turbulence. And it is also shown that it is the Reynolds number rather than Mach number that acts as a key similarity parameter in constructing their coupling.

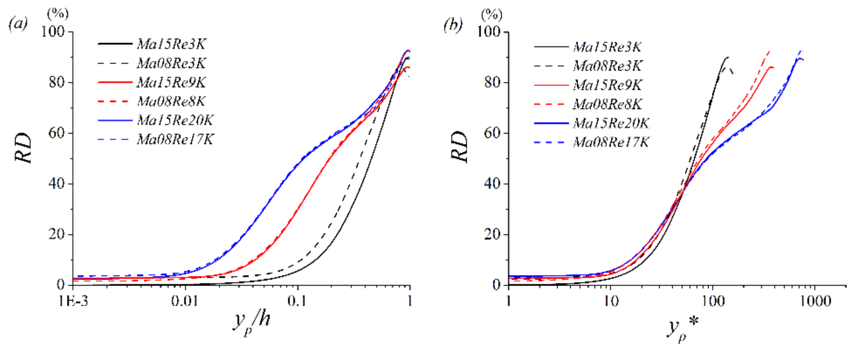

Figure 1. (a) Relative deviations as functions of y_p/h for all the cases; (b) relative deviations as functions of y_p^* for all the cases.

Acknowledgements

L.F. acknowledges the fund from the Research Grants Council (RGC) of the Government of Hong Kong Special Administrative Region (HKSAR) with RGC/ECS Project (No. 26200222).

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A Novel Flow Control Method Incorporating the Riblet Technique on Cascade profile and Experimental Validation

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Abstract: For the purpose of reducing the flow loss in the compressor cascade, the aerodynamic design of the blade geometry is essential. The traditional aerodynamic design focuses on curve modification, and the surface structure design is rarely considered in the optimization framework. Recent studies have revealed that micro riblet surface provides an excellent application prospect in drag reduction, which offers a new idea for the design of compressor cascade. In this paper, a concept of "geometry-flow loss" control is proposed, and an innovative optimization method combining profile and riblet design is developed further to improve the aerodynamic performances of the compressor cascade. In the design process of multiple iterations, the multi-scale simulations describing the whole flow field with a massive amount of grids would cause unaffordable costs. Therefore, the blade-riblets simplified simulation strategy is employed to evaluate the aerodynamic performances of the cascade profile with riblets and make the profile with riblet design practicable. The flow loss characteristics of the original cascade and two optimal cascades are assessed and verified by wind tunnel tests. The simulation and experimental results both indicate that the profile with the riblet design significantly further reduces the total pressure loss of the compressor cascade compared to the traditional profile design. The proposed concept in this paper increases the dimensionality of the geometry design and further exploits the design potential of the compressor cascade.

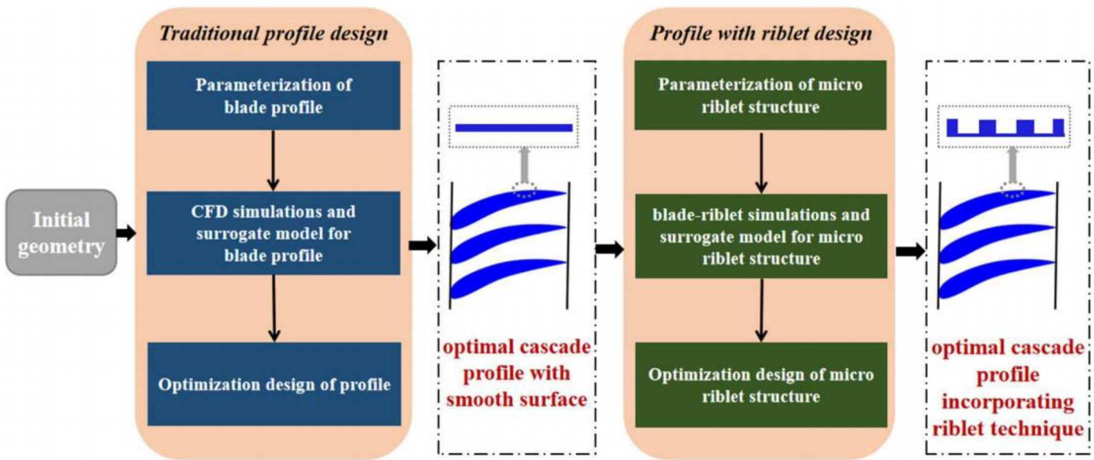

Figure 1. The flow diagram of profile with riblet design.

A new low-dissipation finite-volume method based on the TENO scheme for unstructured meshes

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Abstract: The development of high-order low-dissipation shock-capturing scheme is challenging for compressible fluid simulations, due to the presence of discontinuities, e.g., shock and contact waves, and broad-band continuous flow scales. As one of the state-of-the-art high-order numerical reconstruction schemes, the family of high-order targeted ENO (TENO) schemes proposed by Fu et al. [1] has been demonstrated to perform well for compressible gas dynamics on structured meshes and recently extended to unstructured meshes by Ji et al. [2]. The core novelty of the high-order TENO schemes relies on the ENO-like stencil selection process, which either deploys the candidate stencil with the optimal linear weight or completely suppresses its contribution when crossed by a discontinuity. Such a sharp stencil selection guarantees the resulting low-dissipation TENO scheme recovers the background linear scheme exactly up to intermediate wavenumber. However, when handling the other typical procedure in the finite volume framework, i.e., solving the Riemann problem to determine the cell interface flux, all Riemann solvers currently available for unstructured meshes are applied indiscriminately with additional dissipation aimed at achieving stable shock-capturing. Consequently, the resultant interface flux calculation process of smooth flows become unnecessarily dissipative due to the additional dissipation although it is indispensable for the non-smooth flows.

In this work, with the observation that the TENO scheme not only provides the reconstructed data at the cell interface but also classifies the local flow scales as smooth or non-smooth on the discretized mesh, we propose a novel low-dissipation finite-volume method based on the high-order TENO scheme for unstructured meshes. This new method provides a separate control over the numerical dissipation of the reconstruction stage and the flux computing stage in a unified framework and leads to a resultant finite-volume method with the extremely low-dissipation property. Without parameter tuning case by case, a set of benchmark cases has been conducted to assess the performance of the proposed method.

Acknowledgements

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High-precision aerodynamic and noise simulation of helicopter rotor hovering and forward flight

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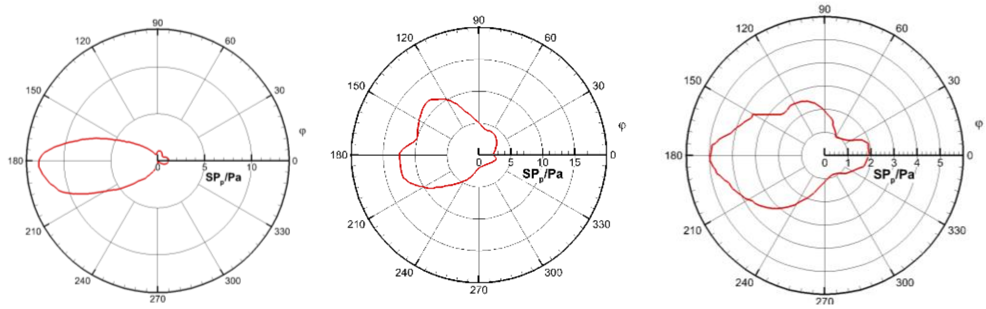
Abstract: Based on the static/motion overlapping grid, the high precision prediction of the hovering/forward flight compressible laminar and turbulent flow fields of the helicopter wing body is achieved by using the Finite Volume Method. Combining high-precision numerical simulation and industrial application experience formula, a coupled trim strategy was developed to efficiently trim the rotor and fuselage under maneuvering state, such as variable pitch and swing, and then the noise problem of hovering and forward flight of a helicopter including the main rotor and other air components was effectively simulated and the results were analyzed. The results show that: Rotor noise during low-speed forward flight is mainly divided into discrete noise related to blade rotation frequency and wide-band noise related to turbulent pressure pulsation frequency on blade. The attenuation of the noise signal of the rotor's high-order harmonics is relatively fast. The main area of noise radiation is concentrated in the low-frequency region, which is close to the main frequency of the rotor rotation cycle, that is, the dominant part is discrete noise. However, with the increase of forward ratio, obvious nonlinear quadrupole noise (high-speed pulse noise) appears when the tip Mach number reaches the transonic state, so it is more difficult to calculate and capture the noise at large forward ratio. Through the directivity analysis of the three-dimensional sound pressure radiation, it is verified that the rotor noise mainly affects the forward area of the rotor disk, and the sound pressure pulsation under the forward blade is more prominent because of the downwash flow field induced by the blade rotation.



(a) plane XOY (b) plane XOZ (c) plane YOZ

Figure 1. Peak radiation directivity of far-field noise sound pressure pulse in different planes of AH-1g rotor in operating condition No. 10014 (R=3.44r)

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Enstrophy production in compressible isotropic turbulence with vibrational non-equilibrium

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Abstract: High-temperature compressible turbulence occurs in many fascinating physical problems and applications, including supersonic combustion of air-breathing propulsion systems, high-enthalpy flows associated with hypersonic vehicles, and objects entering a planetary atmosphere, etc. The elevated temperature in compressible turbulence may give rise to many processes, such as vibrational energies excitation. Furthermore, any redistribution of internal energy among different modes owing to a change of environment requires a number of molecular collisions and hence a certain characteristic time, which closely depends on the conditions of temperature and pressure. When the characteristic time for redistribution (relaxation time) by molecular collision is of the same order as the time scale of fluid flow, the nonequilibrium effect must be taken into account, and it is said to be in thermal nonequilibrium.

In this work, the enstrophy production is numerically investigated for statistically stationary compressible isotropic turbulence in vibrational non-equilibrium with a large-scale thermal forcing. The net enstrophy production term is decomposed into solenoidal, dilatational and isotropic dilatational terms based on the Helmholtz decomposition. From the full flow field perspective, the net enstrophy production mainly stems from the solenoidal term. For the dilatational and isotropic dilatational terms, although their local magnitudes can be considerable, the positive values in the compression region and the negative values in the expansion region cancel out on average. For the solenoidal component of the deviatoric strain-rate tensor, the statistical properties of its eigenvalues and alignments between vorticity and its eigenvectors are nearly independent of the local dilatation and vibrational relaxation. The solenoidal components of enstrophy production along three eigendirections are thus mainly affected by the vorticity. For the dilatational component of deviatoric strain-rate tensor, the statistical properties of its eigenvalues and alignments between vorticity and its eigenvectors closely relate to the local dilatation and vibrational relaxation. The dilatational components of enstrophy production along three eigendirections are therefore affected by the vorticity, eigenvalues and alignments between the vorticity and eigenvectors.

Acknowledgements

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A new SPH method based on high-order moving-least-square TENO scheme for compressible flows

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Abstract: In this work, we establish a hybrid high-order SPH framework (MLS-TENO-SPH) for compressible flows with discontinuities, which is able to achieve genuine high-order convergence in smooth regions and also capture discontinuities well in non-smooth regions. The framework can be either fully Lagrangian, Eulerian or realizing arbitary-Lagrangian-Eulerian (ALE) feature enforcing the isotropic particle distribution in specific cases. In the proposed framework, the computational domain is divided into smooth regions and non-smooth regions, and these two regions are determined by a strong scale separation strategy in the TENO scheme. In smooth regions, the moving-least-square (MLS) approximation is used for evaluating high-order derivative operator, which is able to realize genuine high-order construction; in non-smooth regions, the new TENO scheme based on Vila's framework with several new improvements will be deployed to capture discontinuities and high-wavenumber flow scales with low numerical dissipation. The present MLS-TENO-SPH method is validated with a set of challenging cases based on the Eulerian, Lagrangian or ALE framework. Numerical results demonstrate that the MLS-TENO-SPH method features lower numerical dissipation and higher efficiency than the conventional method, and can restore genuine high-order accuracy in smooth regions. Overall, the proposed framework serves as a new exploration in high-order SPH methods, which are potential for compressible flow simulations with shockwaves.

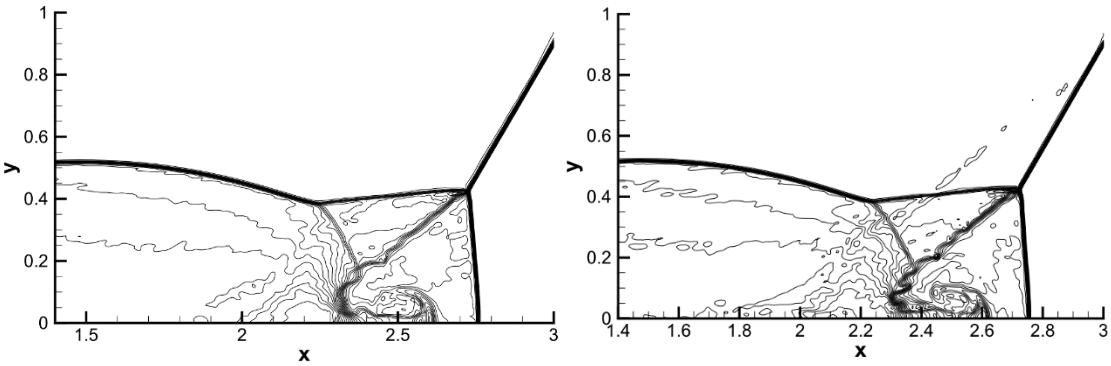

Figure 1 Double Mach reflection problem: the density fields are simulated using MLS-TENO-SPH method, and the comparison of 4th and 6th order accuracy is presented on the left and right, respectively.

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A robust compact Least-Squares reconstruction method for compressible turbulent flow simulations of complex configurations

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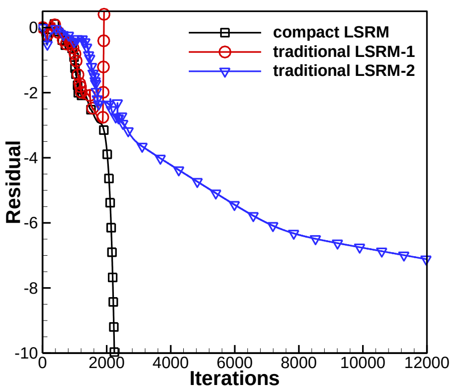
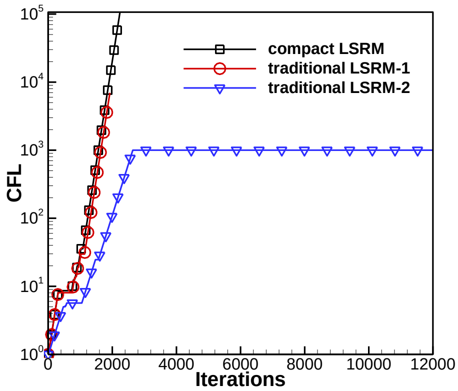
Abstract: For the second-order finite volume method, implicit schemes and reconstruction methods are two main algorithms which influence the robustness and efficiency of the numerical simulations of compressible turbulent flows. In this paper, a compact Least-Squares reconstruction method is proposed to calculate the gradients for the distribution of flow field variables approximation. The compactness of the new reconstruction method is reflected in the gradient calculation process. The geometries of the face-neighboring elements are no longer utilized and weighted average values at the centroid of the interfaces are used to calculate the gradients instead of the values at the centroid of the face-neighboring elements. Meanwhile, an exact Jacobian solving strategy is developed for implicit temporal dis-cretization. The accurate processing of Jacobian matrix can extensively improve the invertibility of the Jacobian ma-trix and avoid introducing extra numerical errors. In addition, a modified Venkatakrishnan limiter is applied to deal with the shock which may appear in transonic flows and the applicability of the mentioned methods is enhanced further. The combination of the proposed methods makes the numerical simulations of turbulent flow can converge rapidly and steadily with an adaptive increasing CFL number. The numerical results of several benchmarks indicate that the proposed methods perform well in robustness, efficiency, accuracy, and have good application potential in turbulent flow simulations of complex configurations.



(a) Density



(b) *CFL* number

Fig. 1. The convergence history of density and the increasing history of *CFL* number (compact LSRM: $CFL_{max} = 10^6$, traditional LSRM-1: $CFL_{max} = 10^6$, traditional LSRM-2: $CFL_{max} = 10^3$)

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Kinematic properties of vortical structures in compressible wall-bounded turbulence

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Abstract: Since the early 1950s, the vortex structure has been recognized to play an important role in the dynamics of near-wall turbulence. This work scrutinizes kinematic features of vortical structures, e.g., size, strength, and population, in compressible wall-bounded turbulence using the direct numerical simulations (DNS) database of turbulent channel flows. A satisfactory agreement is achieved for most features among compressible and incompressible cases in the semi-local scaling. Specifically, the size of vortices is larger and larger in the wall-normal distance, while its strength weakens. Regarding the population, the percentage of streamwise vortices continues increasing until the inner edge of the logarithmic region, whereas spanwise vortices occur more and more frequently over the entire logarithmic region and outer layer. These works advance our knowledge of the vortex structures in compressible wall turbulence.

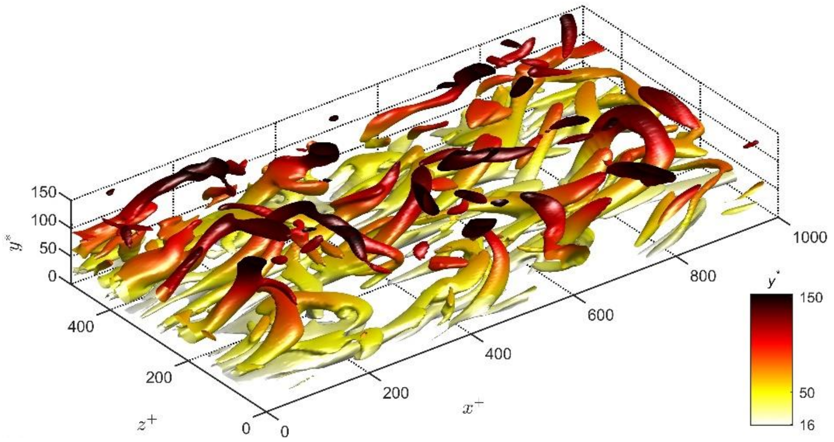

Figure 1. Extracted vortical structures in the instantaneous field at *Ma*=1.5.

Acknowledgements

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Risk assessment of life loss in floods in a coastal city based on the hydrodynamic model

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Abstract: Many coastal cities are threatened by flood disasters by extreme weather such as typhoons and rainstorms, which result in serious economic losses and infrastructure damage. Flood risk assessment can help with disaster prevention and improve urban resilience. This study assessed the loss of life induced by the flood disaster in the coastal cities of Macao Peninsula during the typhoon. The joint probability of storm surge and rainfall is estimated using the copula function. A coupled hydrodynamic model of the drainage and overland model is established to simulate the flooding on Macao Peninsula. The flood simulated by the hydrodynamic model is used to quantitatively evaluate the flood during the typhoon. The numerical simulation of the flooding process considered the hydrodynamic interaction between the land surface and the drainage pipes. The flood damage to people was evaluated based on human vulnerability in floods. The life loss could be estimated based on the characteristics of the simulated flood scenario obtained from the flood model. Flood risk is quantitatively assessed through the probability of flood occurrence and loss of life in floods. The maximum simulated flood depth is about two meters during the typhoon through the flood model. The coastal area in the western part of the Macao Peninsula is more vulnerable to floods and has higher mortality than other areas. Due to the high population density, this area has a higher probability of potential loss of life in extreme floods. This study is helpful for flood disaster assessment and urban flood control for coastal areas.

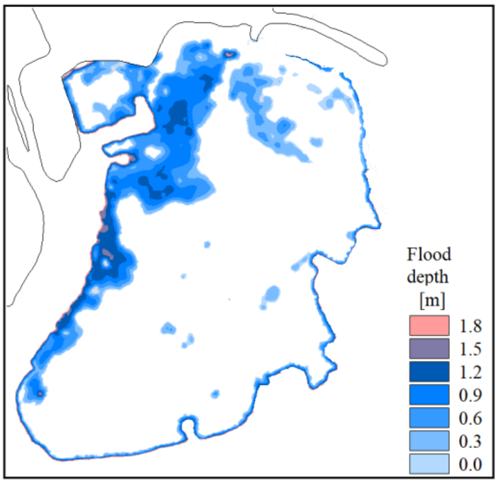

Figure 1. The simulated flood depth during Typhoon Mangkhut in Macao Peninsula.

Acknowledgements

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Experimental study on dynamic shear modulus and liquefaction resistance of coral sand under cyclic loading

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Abstract: To evaluate the effect of fine-grained soil (FS), relative density and stress level on the shear modulus and liquefaction resistance of coral sand, a set of undrained hollow torsional shear and resonant column tests were carried out. Test results demonstrated that equivalent skeleton void ratio has a unique power relationship with the normalised maximum dynamic shear modulus. Besides, pore water pressure (PWP) developing process of pure coral sand and mixtures present three stages along with the rate of PWP ratio (PWP to effective confining pressure) as shown in Fig. 1. Test outcomes showed that terminal PWP ratio has a positive relation with effective confining pressure and cyclic stress ratio (CSR), and the liquefaction degree was aggravated at high stress level. Nevertheless, the cycle number to cause liquefaction has a negative relation with FS content or stress level. FS can improve the liquefaction resistance of mixtures. Furthermore, for a given shear strain, dynamic shear modulus decreases with increasing fine content, increases with increasing relative density and effective confining pressure. The curves of the maximum dynamic shear modulus rate (G/Gmax) tend to decline with increasing fine content, while relative density and stress level have little influence on G/Gmax.

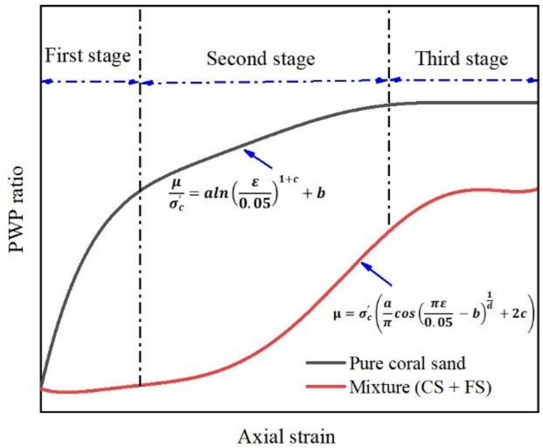

Fig. 1 PWP developing process of pure coral sand and mixture

Acknowledgements

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Centrifuge and numerical modelling of the structurally cemented stone column-seawall system

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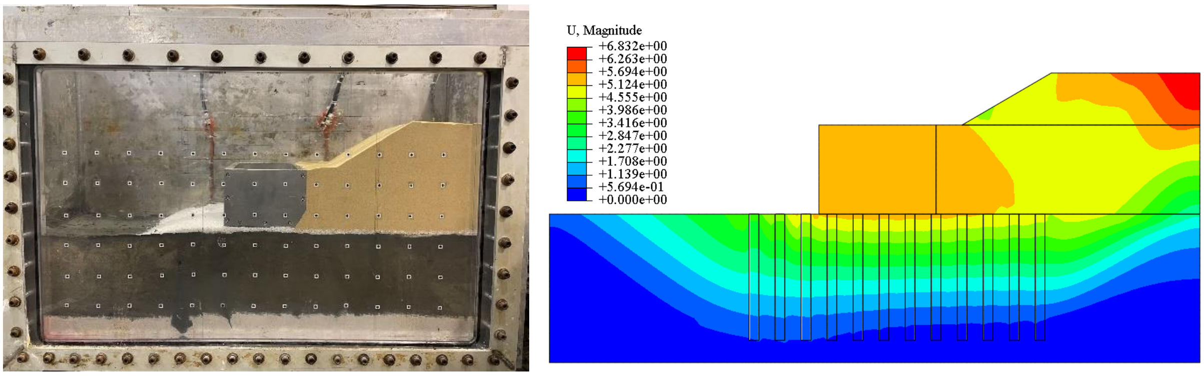
Abstract: This study focuses on centrifuge and numerical modelling of a structurally cemented stone column-seawall system for environmentally friendly reclamation. In this study, a centrifuge test is performed to investigate the reinforcement mechanism and interaction between sea mud and structurally cemented stone columns. The experimental results of the centrifuge test are discussed, including the undrained shear strength profile of the marine deposit, the deformation of the seawall and backfill soil, the change of pore water pressure in the sea mud, pressure distribution on the top of stone column and the movement of marine clay. In addition, a finite element analysis is performed to simulate the centrifuge model according to the prototype scale. The calculation results are generally consistent with the actual test results, which verifies the rationality of parameter selection. Finally, a grid seawall system is proposed to improve the seawall stability and reduce its deformation.



(a) (b)

Figure 1. (a) Centrifuge modelling of the structurally cemented stone column-seawall system; (b) Displacement field of numerical model of the structurally cemented stone column-seawall system.

Acknowledgements

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Earth Pressure Distribution of Offshore Monopiles with Different Slenderness

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Abstract: By means of 3D finite element modelling, we investigate the slenderness effect of monopiles on soil deformation and the associated earth pressure distribution under lateral loading. We show that the magnitude of either normal contact stress or shear stress at a pile section decreases with increasing pile diameter, but the distribution pattern of the normalized one is nearly the same. Furthermore, we show that the widely-accepted theoretical distribution of shear stress is inappropriate due to neglecting the relative slip and gap between pile and soil.

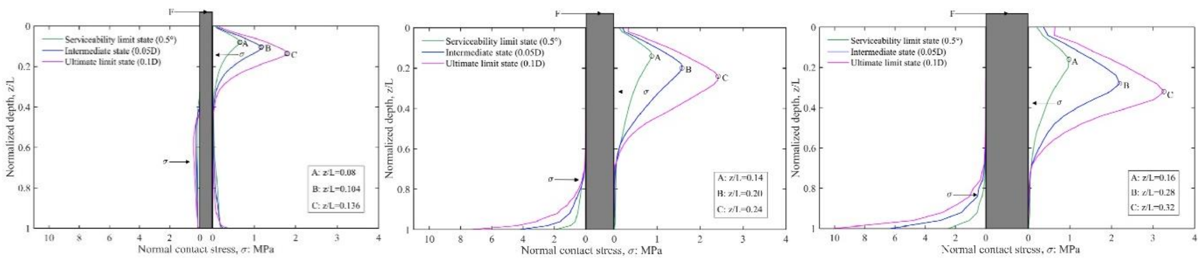
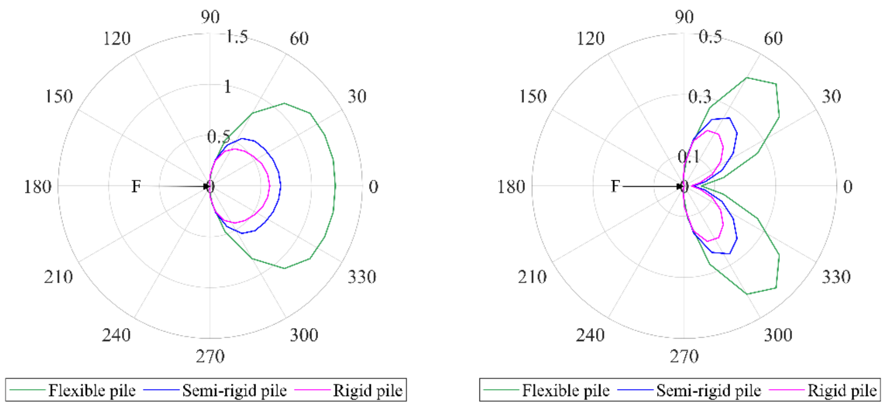


Figure 1. Normal contact stress distribution of flexible pile, semirigid pile and rigid pile, respectively.



(a) Normal contact stress (b) Shear stress

Figure 2. Contact stresses (in MPa) across pile perimeter (depth=2 m and section displacement=120 mm).

Acknowledgement

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Reference

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Study on Settlement of Immersed Tunnel Segment Based on 3D Numerical Manifold Method Considering Uneven Back Silting and Complex Strata

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Abstract: Immersed tunnel has been adopted worldwide due to its environmental friendliness and adaptability to diverse geological conditions. However, the uneven settlement of immersed segments, caused by factors such as poor foundation, silting during construction, water flow and wave action, uneven silting, etc., has posed significant challenges to their long-term serviceability. Traditional FEM requires a large amount of computation when simulating complex strata, and cannot efficiently simulate the interface between structure and soil. This study introduces a numerical simulation method that combines Voxel Crack Model (VCM) with Numerical Manifold Method (NMM) into tunnel engineering research, building a 3D model of the E17 section of the Hong Kong-Zhuhai-Macau Bridge tunnel. The Model present complex discontinuous surfaces in multiple strata and uneven back silting during the serviceability of tunnel. Results shows that uneven back silting can lead to significant settlement differences, and the introduced NMM is verified to be effective in settlement simulation for immersed tunnel with high efficiency, making it a valuable tool for real-world engineering applications.

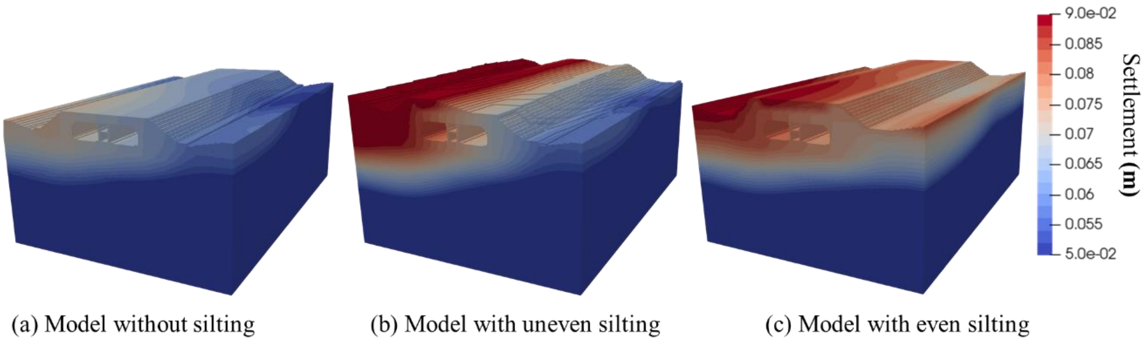

Figure 1. Cloud maps of the settlement of tunnel in different conditions

Acknowledgements

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Numerical Simulation of Coastal Breakwater Using Signed Distance Field-based fully resolved Coupled CFD-DEM

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Abstract: Understanding Fluid-Structure Interaction (FSI) is critical to safety of coastal infrastructure and coastal engineering. In this study, we present a computational study of coastal breakwaters using a signed distance field (SDF) enhanced fully resolved coupled computational fluid dynamics (CFD) discrete element method (DEM). Multiphase fluids are modelled using CFD based on finite volume method and volume of fraction approach, whereas particles with irregular shapes are modelled using SDF-DEM. The SDF-CFD-DEM enables fully and robust consideration of arbitrarily shaped granular particles and consistent and efficient implementation of the fluid-particle interaction in fully resolved CFD. The model is first validated by analytical solutions and experimental data. It is then employed to simulate the response of breakwaters of different packing configurations subjected to the impact of waves. Potential internal erosion within the breakwater is examined systematically. The proposed approach offers a promising high-fidelity computational tool to model complex fluid-particle systems.

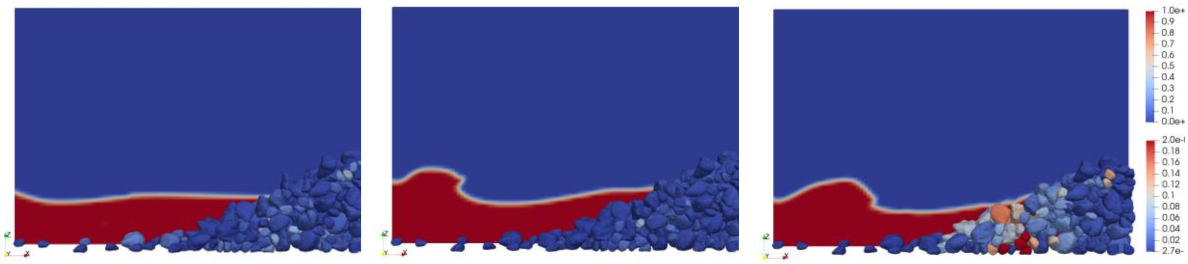

Figure 1. SDF-CFD-DEM simulation of wave impacting a breakwater

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Numerical Simulation of Granular System under Cyclic Excitation using Discrete Element Method

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Abstract: Granular materials are ubiquitous both in nature and in industry. Because the granular system is a non-thermal system. It will break away from the quasi-static state and have specific motion behaviour only when it is subjected to external excitation. However, the granular system is highly sensitive to external excitation: different excitation often leads to different motion characteristics. Therefore, the behaviour of granular has a high degree of complexity. In this article, granular size segregation and granular crystallization when the granular system under the action of unsteady cyclic excitation are repeated by using discrete element method (DEM).

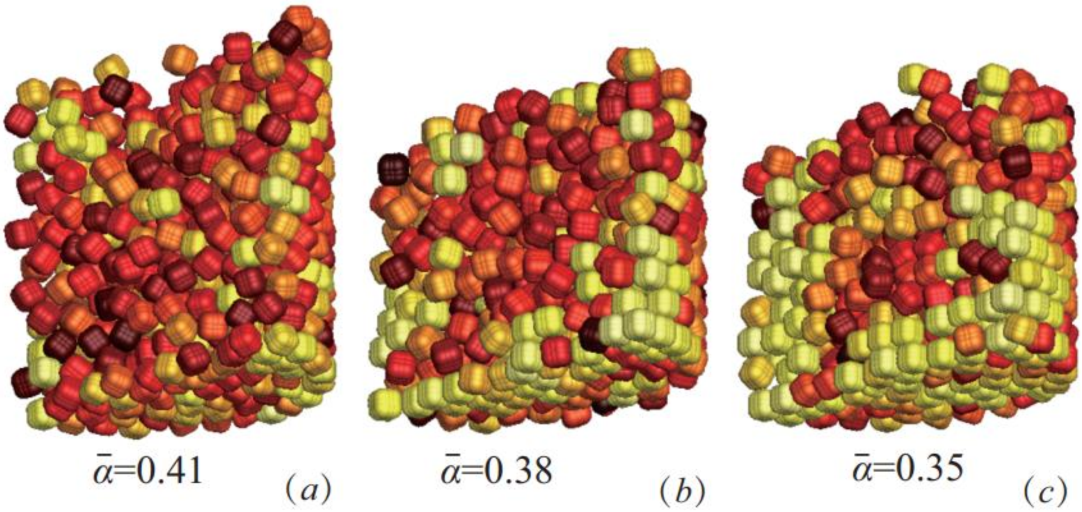

Figure 1. Granular crystallization obtained by DEM under different gravitations.

Acknowledgements

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Verification of unsaturated shear strength theory of expansive soil using conventional direct shear test

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Abstract: In this paper, an unsaturated strength theory considering the microstructural properties of expansive soil was introduced, where the parameters have explicit physical meanings and determination methods. A series of conventional tests, including the filter paper method and conventional straight shear test, were carried out to validate the unsaturated shear strength theory. Soil-water characteristic curves of soil samples with different dry densities were measured by the filter paper method, from which the pore distribution of the soil was obtained and furtherly the matrix suction. Then the strength of unsaturated soil was predicted by shear strength theory using matric suction and moisture content.

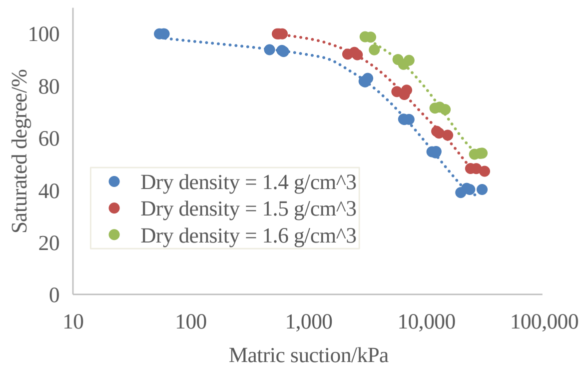

Figure 1. Relationship between saturated degree and suction for expansive soil with different dry densities.

Acknowledgments

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A new time-domain dynamic response reconstruction method based on model condensation

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Abstract: Structural dynamic response reconstruction of large-scale civil engineering structures by traditional methods results in heavy computational burden with low efficiency. A new time-domain response reconstruction method (see Figure 1) based on model condensation is carried out to release the computation burden. Depending on the characteristics of the target structural system, the dimensions of the condensed system matrices can be much smaller than those of the original finite element model. Band-pass filters are used to decompose the measured structural responses to identify the important modes for response reconstruction. The transformation matrix is computed based on the modal matrices of the condensed model. It must be pointed out that no excitation information is needed in the proposed method. The dynamic responses at sensor-inaccessible locations can be reconstructed by the proposed method through modal superpositions and coordinate transformations. A numerical and an experiment case study were employed in this paper to verify the efficiency and accuracy of the novel response reconstruction method. In the experimental case study of a two-story steel frame, modal identification and model updating were carried out based on the measured acceleration data. The results of both the numerical and experimental case studies show the superior performance of the proposed method when compared to traditional methods.

Keywords: response reconstruction, large-scale structures, model condensation, modal identification, model updating

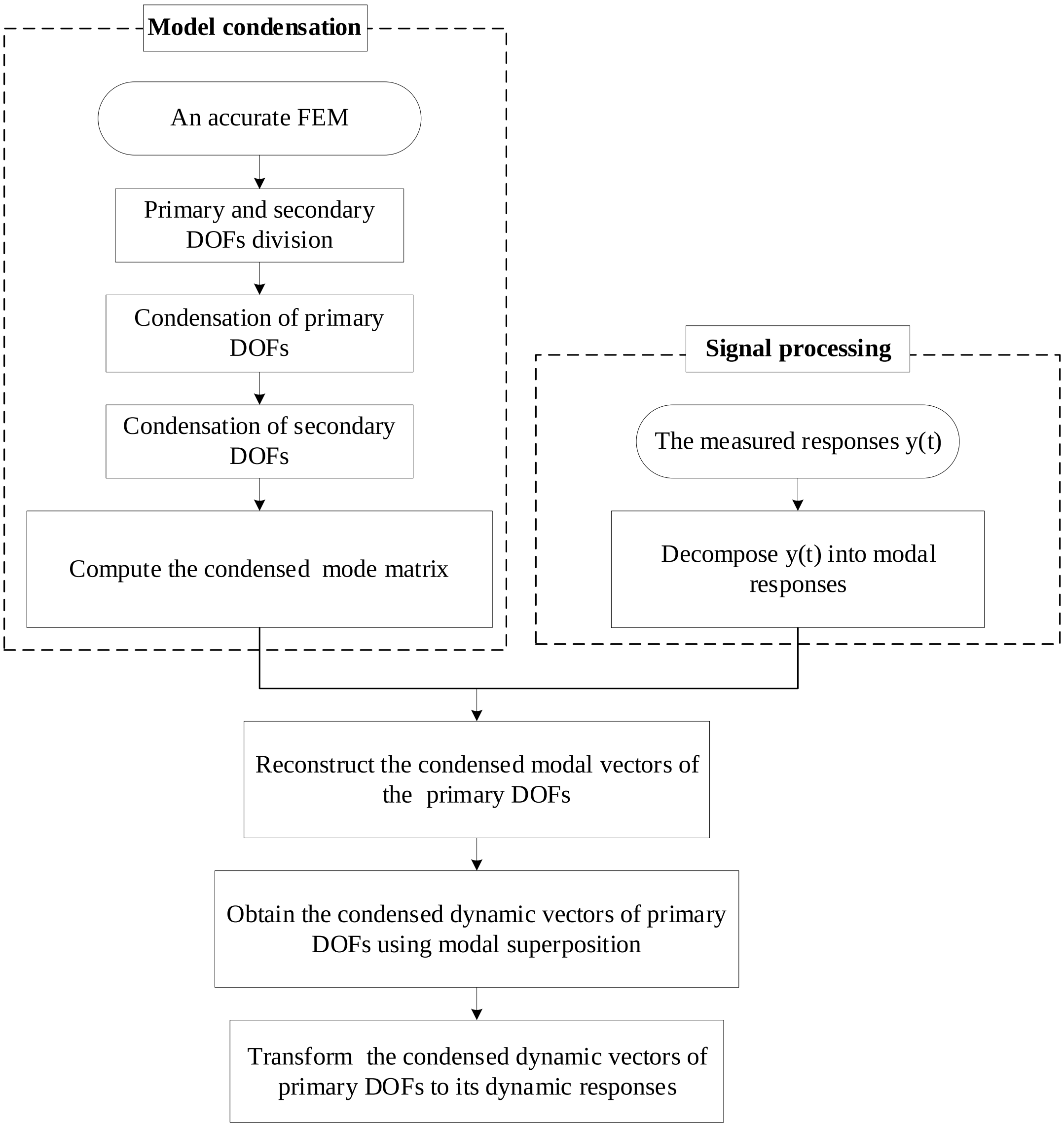

Figure 1. Flowchart of the response reconstruction method

Acknowledgments

This study was supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. R5020-18 [RIF 8799008]).

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Dynamic Boundaries in Material Point Method for Seismic Analysis

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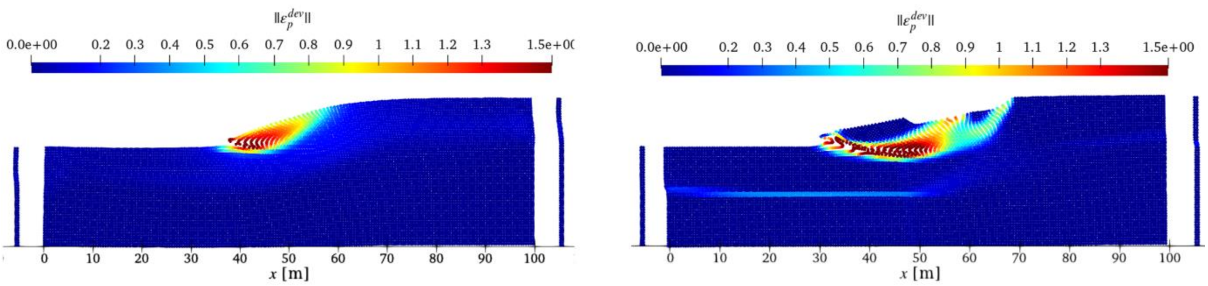
Abstract: Material Point Method (MPM) is a powerful numerical tool for simulating large deformations. However, difficulty to impose proper dynamic boundaries in MPM hinders its application in seismic analysis. In this study, we propose a method to implement the transmitting boundary and free-field boundary in MPM, in which particle tractions (Nairn and Guilkey 2015) are accurately applied to allow for large deformations (e.g., across cells) especially under strong earthquakes. A benchmark case is conducted to validate the developed model for wave propagation in an elastic slope. It is found that the dynamic boundaries enable accurate earthquake input and effectively avoid the wave reflections at model boundaries for both shear waves and compression waves. Then, an elastoplastic slope model is developed to investigate the effects of wave type, slope geometry and soil properties on the failure mode of the slope during earthquakes. It is found that generation of shear bands has more significant damping effects on the propagation of shear wave than that of the compressive wave. In addition, failure of a sandy slope mainly occurs at a shallow depth, while a clayey slope usually generates a deeper sliding surface or even multiple shear bands, as shown in Fig. 1. Further studies are under way to consider the hydromechanical coupling effects in seismic analysis.



(a) (b)

Figure 1. Comparison of failure patterns between (a) a sandy slope and (b) a clayey slope.

Acknowledgements

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Prediction of spatial behaviour of immersed tunnel joint using machine learning method

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Abstract: As critical connecting components of the immersed tunnel, immersion joints are highly vulnerable and sensitive to environment changes, which should be monitored by structural health monitoring system as shown in Fig. 1. However, the system faces challenges of insufficient monitoring data. In immersed tunnel of Hong Kong-Zhuhai-Macao Bridge, the health monitoring system includes 34 groups of axial displacement data while only 7 groups of structural temperature data are available, making it difficult to analyse the joint performance. In this study, physical and spatial correlations between axial displacement and limited structural temperature data are established using simple regression models, with their coefficients estimated by Bayesian optimization method. The spatial characteristics of immersion joints are adopted as inputs to predict the regression coefficients using machine learning models such as Linear Regression, Ridge Regression, and genetic programming. The results show that there is a certain spatial correlation among tunnel joints, and Ridge Regression could capture this correlation and outperforms other methods in terms of accuracy and generalization performance.

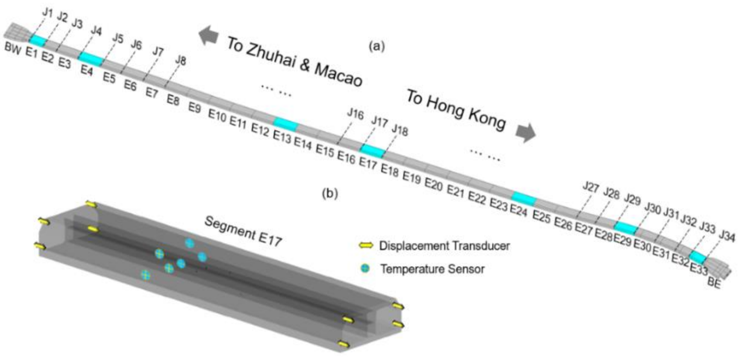

Fig. 1 Layout of HZMB immersed tunnel with segments equipped temperature sensor highlighted (a) and sensor settings for Segment E17 (b).

Acknowledgements

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The study of foreign object damage law at different positions of aero-engine blade

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Abstract: In order to study the differences in damage characteristics caused by foreign objects at different locations of aero-engine fan blades, a 6-mm, 304 steel pellet was used as a foreign object, and a three-dimensional finite element model was constructed based on the rate-dependent intrinsic model by conducting foreign object damage tests at different impact locations through a light gas cannon, and the predicted FOD damage areas were compared with the experimental results, and a high degree of agreement was achieved between the two. The effects of impact location as well as impact angle on the trend of impactor velocity were investigated using the constructed finite element model. The results show that the leaf tip is weaker and more prone to penetration type damage patterns compared to the leaf root and leaf basin locations; it is also found that the transformation trend of the residual velocity of the impactor differs with different damage patterns.

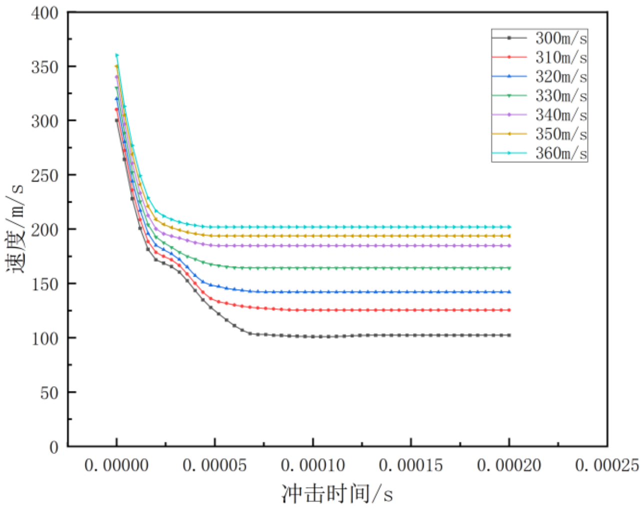

Figure 1. Transformation curve of impact response speed at 90° angle.

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3D printing of nanopillar-structured $CH_3NH_3PbI_3$ perovskite with high stability and flexibility

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Abstract: Hybrid perovskite materials have attracted significant attention in recent years due to their unique optoelectronic properties. Among them, $CH_3NH_3PbI_3$ is one of the most promising hybrid perovskite materials that has been widely studied. However, despite the extensive research, the fabrication methods and the mechanical properties of $CH_3NH_3PbI_3$, which are crucial for determining the stability and reliability of the material, remain poorly understood. In this study, we present a novel approach for fabricating $CH_3NH_3PbI_3$ nanopillars using a meniscus containing femtoliters of ink that guides the solution-mediated evaporation-driven crystallization in midair. Furthermore, we conducted a compression test on $CH_3NH_3PbI_3$ nanopillars using an atomic force microscope (AFM) cantilever to study their mechanical behavior. Our results demonstrate that the successfully fabricated nanopillars exhibit a compressive strength of approximately 97 MPa and are capable of recovering, indicating their high potential ability to be used in advanced flexible optoelectronic devices. Our findings provide valuable insights into the mechanical properties of $CH_3NH_3PbI_3$ nanopillars, which could inform the development of new perovskite materials with improved mechanical stability for various applications.

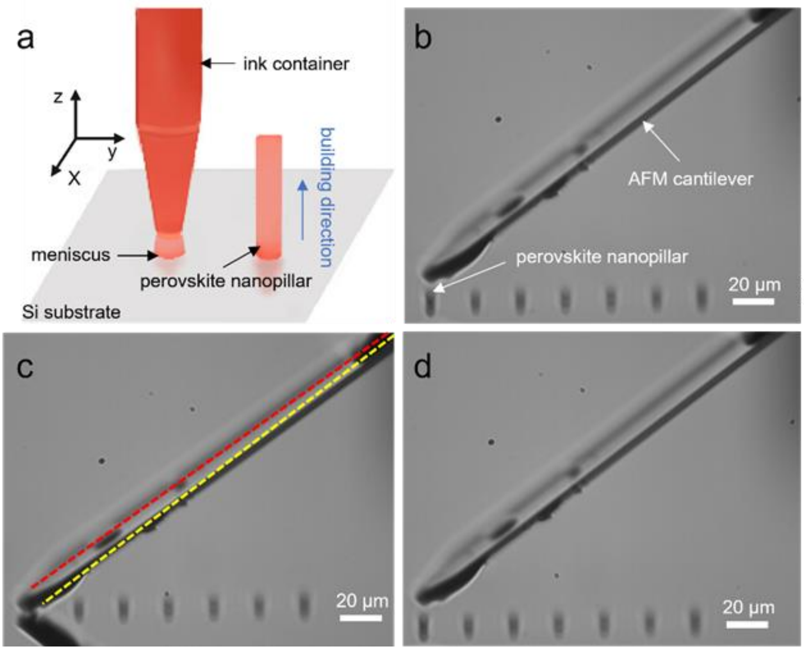

Figure 1. (a) Schematic of the printing process of the $CH_3NH_3PbI_3$ nanopillars. (b-d) Compression test of $CH_3NH_3PbI_3$ nanopillars using an atomic force microscope (AFM) cantilever. (b-d) A series of side-view optical micrographs in the pressing process: (b) a cantilever with a length of approximately 175 μm and a spring constant of 3 N/m was positioned at a distance of a few micrometres away from a nanopillar with a diameter of approximately 600 nm and a height of approximately 5 μm. (c) the AFM cantilever contacts with the nanopillar under pressing. The yellow dash line denotes the initial cantilever axis direction, while a red line shows the bent cantilever axis direction at the end of compression. (d) the recovery posture after compression.

Machine Learning-Based Prediction of Morphological Configuration and Mechanical Behavior of Kirigami-Inspired Programmable Active Composites

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Abstract: Kirigami-inspired designs hold great potential for the development of functional materials and devices, but predicting the morphological configuration of these structures under various loading conditions remains a challenge for traditional experimental and simulation methods. Here, we present a novel approach that utilizes machine learning to accurately predict the deformation and stress field of kirigami-inspired programmable active composites. To train our model, first we used a chemical corrosion algorithm to generate a dataset of kirigami-inspired imaging model accompanied by utilizing finite element simulations to obtain their deformation and stress fields as the ground truth, and then trained the deep learning model to offer robust predictions of the displacement and stress fields of the designated structures. Our results demonstrate the effectiveness of this approach in predicting the mechanical behavior of kirigami-inspired active structures, paving the way for the development of advanced and functional composite designs that are programmable and active.

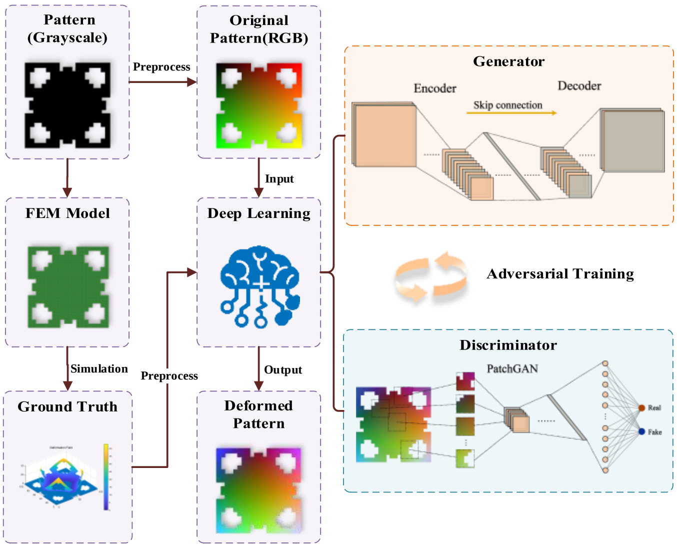

Figure 1. Overview of the proposed work in the kirigami-inspired programmable active composites.

Acknowledgements

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Molecular Dynamics Simulation of the Diffusion Coefficient of Ions Through Graphene Nanopores

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Abstract: Ions transport through nanoscale confinements is of great importance in various areas, such as energy conversion, energy storage, and desalination. The diffusion of ions is an important transport property and may determine the performance of diffusion-dominated systems. Nevertheless, most of the previous studies on ion transport are driven by external pressure gradients and electric fields to obtain the streaming velocities of ions. As the essential role in certain energy systems, the diffusion coefficient D of ions has not been extensively studied. In this study, we investigate the diffusion coefficient of K^+ and Cl^- through graphene nanopores driven by concentration gradients by molecular dynamics simulations. The D is sensitive to the pore size when the pore diameter is smaller than 3 nm and independent on pore size for larger pores. The dependence of D on the porosity shows a near-linear relationship. The energy barriers of ions diffuse through the graphene nanopore with different diameters and porosity are studied. A general scaling law for the D is also proposed.

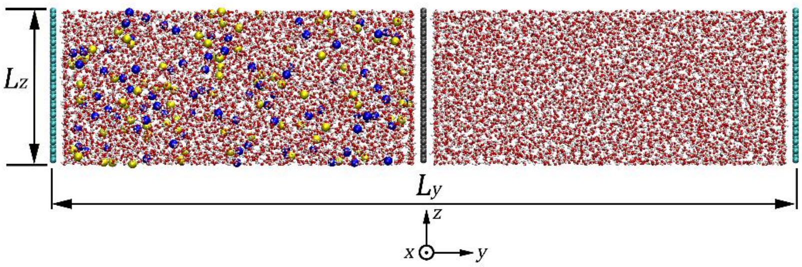

Figure 1. Snapshot of a simulation system.

Acknowledgements

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An efficient search algorithm of fracture angle of IFF criterion and the progressive damage model considering strain-rate effect

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Abstract: Puck's IFF criterion has been widely adopted by researchers due to its accurate description of deformation and failure evolution in composite materials. In this paper, a fast search algorithm for potential fracture planes and a progressive damage model with correction of strain-rate effect are proposed. Firstly, the maximum values of three fracture plane tractions are calculated according to the converted cosine function expression, and the angle corresponding to the largest of the four stress exposures is selected as the starting point. Then the maximum of the stress exposure curve is determined using the GSS algorithm. Furthermore, the modules, strengths and critical energy release rates at different strain rates are fitted with a logarithmic function form and the correction coefficients are calculated. Based on above work, a user subroutine of ABAQUS VUMAT for the novel progressive damage model is built. To verify accuracy of the novel model, a series of dynamic compression tests under loading rates ranging from 0.001/s to 1200/s with different ply orientations are conducted. The comparison of results shows good agreement and the novel progressive damage model can accurately predict onset and crack propagation in composite materials.

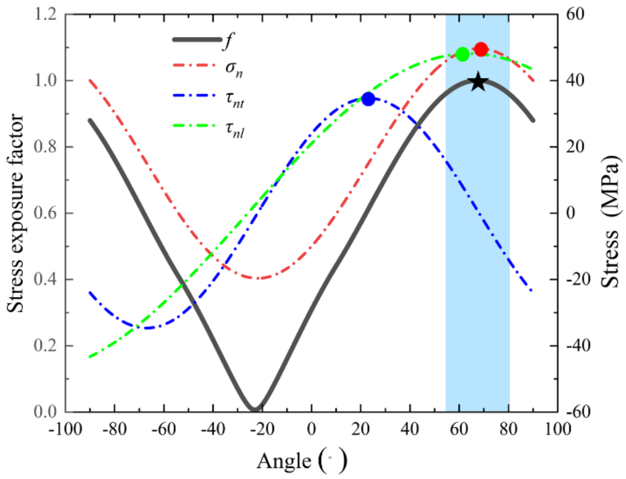

Figure 1. The calculation flow diagram of the improvement searching algorithm

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A Mechanical Stress Control Method in Silicon-Based Anodes for Enhancing Cycling Performance of Lithium-Ion Batteries

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Abstract: This work investigates the utilization of stress-control charging strategies derived from stress analysis of a silicon particle to improve the cycling performance of silicon-based lithium-ion batteries. A mechanochemical model coupled with the free volume theory is used to analyze the stress evolution in the silicon particle under multi-stage current strategies for charging at different levels of state of charge (SOC). The results of the calculations indicate that the proposed strategies reduce the stresses in the silicon particle. Additionally, experimental tests involving cycling test and scanning electron microscopy (SEM) analysis confirm the feasibility of the proposed strategies. These results suggest that multi-stage currents for lithiation and a constant current for delithiation can effectively enhance the cycling performance of silicon-based lithium-ion batteries.

Acknowledgements

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Modeling of elasto-capillary phenomena based on the combined finite-discrete element method

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Abstract: Elasto-capillary phenomena, involving finite deformation of elastomer and elasto-capillary effect of droplet/film, widely exist in biological and micro-electro-mechanical systems. To quantitatively analyze the influence of surface tension and to accurately predict the deformation of elastomer, we develop a finite strain model of hyperelastic materials, and then solve it by the explicit dynamics employing the combined finite-discrete element method (FDEM). Based on our model, we investigate the expansion of a small cavity in elastomer and examine the relation between radius and pressure of cavity. Besides, we explore the deformation of an elastic rod that is immersed in liquid and subjected to surface tension. Results show that when the elasto-capillary effect is neglected, edges of the rod would be unrealistically roughened, while the surface is actually smoothed as the surface tension increases. Moreover, we explore the elasto-capillary effect on advanced multiple-period wrinkling patterns in both planar and curved film-substrate systems, showing that the rough wavy surface can be smoothed by increasing surface tension. Our results not only provide fundamental insights into a variety of elasto-capillary phenomena, but also offer a platform to quantitatively guide rational designs of flexible smart devices actuated by surface tension.

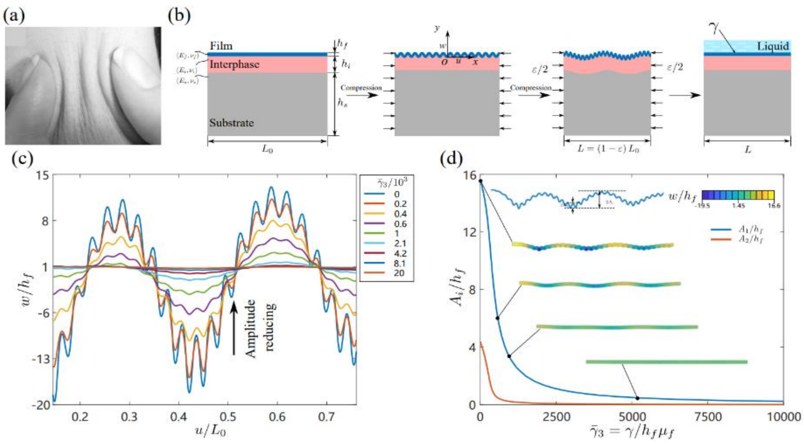

Figure 1. Effect of elasto-capillary on a compressed film-substrate trilayer. (a) Compression hierarchical wrinkles on hand. (b) Schematic of a highly compressed film-substrate trilayer covered by liquid. (c) The hierarchical wrinkling patterns under different surface tensions. (d) The amplitudes A_i (i = 1, 2) as a function of elasto-capillary number $\bar{\gamma}_3$. Insets demonstrate the deflections of the surface layer.

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Coupling Effect of Lamellar Grain Orientation and Micro-Defects on Fatigue Deformation of bimodal Ti-6Al-4V

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Abstract: Fatigue issues of titanium alloys have been a long-standing concern in the aerospace industry. Our recent study reveals that fatigue performance of dual-phase titanium alloy with lamellar structure is strongly correlated with microstructure and micro-defects. Based on the crystal plasticity finite element method (CPFEM), the present work is numerically focused on the coupling effect of lamellar grain orientation and inherent micro-defects on fatigue deformation of bimodal Ti-6Al-4V. In order to efficiently model the microstructural features of titanium alloys, we developed RVE models with various grain size distributions upon an improved VT diagram method. Our numerical results clearly indicate that changes in the orientation of lamellar grains significantly affect the fatigue deformation of bimodal Ti-6Al-4V with prefabricated micro-defects. The angle θ between the lamellar grain orientation and loading direction of RVE models is proposed as a parameter to reflect the orientational effect on fatigue deformation in materials. Moreover, defect size effect on fatigue deformation in RVE models is also systematically discussed, by introducing the parameter of aspect ratio for the designated elliptical defect in bimodal Ti-6Al-4V with lamellar structures. Our findings suggest that these attributes can be applied to the design and manufacturing of titanium alloys with specific purpose of applications.

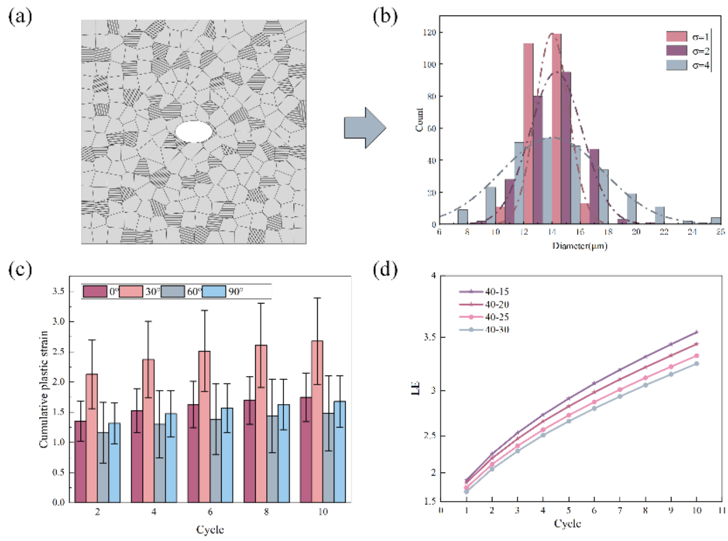

Figure 1. Effect of microstructure and defects on RVE models with a variety of grain distribution

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Collaborative Mechanisms Boost the Nanoscale Boiling Heat Transfer at Functionalized Gold Surfaces

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Abstract: Liquid-vapor phase change heat transfer, i.e., boiling heat transfer, has been demonstrated to be an effective thermal management strategy for high-power electronics and power generators. Improving the boiling heat transfer performance can largely increase the energy conversion efficiency in these corresponding devices. Here, we demonstrate that the boiling heat transfer coefficient (HTC) at functionalized Au surfaces can be improved 3.3 times at most by introducing functionalization groups (FGs) to Au surfaces. Our molecular dynamics simulations show that the increase of HTC results from the high thermal conductance across functionalized Au/water interfaces and the strong interaction between FGs and water molecules. The high interfacial thermal conductance of functionalized Au/water interfaces stems from the strong bonding between the functionalized Au surface and water, and the strong vibrational coupling at 0~4 THz between Au and FGs. The strong interaction between FGs and water molecules comes from their mutual adhesions, including van der Waals and electrostatic interactions and bridging effects. When FGs with electronegative atoms (e.g., -CF_3, -OH, and -COOH FGs) are introduced, hydrogen bonds will form due to their electrostatic interactions, which benefit the thermal energy exchange between FGs and water molecules. The Au-CF_2(COOH) FGs surface, which is designed to include all the mechanisms mentioned above, can therefore increase the boiling HTC by 2.3 times compared to that of the planar Au surface. Our results here provide insights into the design of surfaces with high boiling heat transfer performances using chemical FGs. Our results here provide insights into the design of surfaces with high boiling heat transfer performances using chemical FGs.

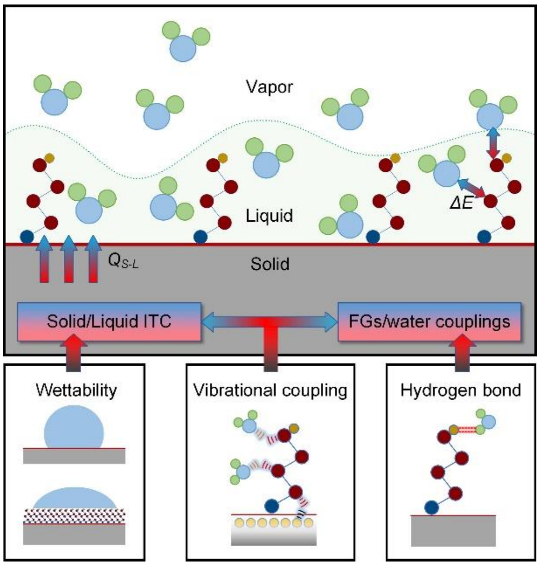

Figure 1. Collaborative mechanisms facilitate boiling heat transfer at functionalized Au surfaces

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A 3D Hard-Magnetic Soft Rod Model

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Abstract: Hard-magnetic soft materials have attracted broad interests because of their flexible programmability, non-contact activation and rapid response in various applications such as soft robotics, biomedical devices and flexible electronics. Such multifunctional materials consist of a soft matrix embedded with hard-magnetic particles, and can exhibit large deformations under external magnetic stimuli. Here, we develop a 3D rod model to predict spatial deformations (extension, bending and twist) of slender hard-magnetic elastica. The model follows Kirchhoff hypothesis and thus reduces the 3D magneto-elastic energy function to a 1D form. Besides, the co-rotational formulation is applied to describe rigid body motion, and explicit time integration is adopted for the nonlinear resolution. Moreover, we explore finite bending and post-buckling of hard-magnetic elastica under external magnetic fields with different directions and amplitudes. Representative examples with various configurations show superior efficiency and accuracy of the model (the difference less than 1% with only a small number of elements) compared to conventional solid element. Our model could be used to guide rational designs on programmable shape morphing of ferromagnetic slender structures.

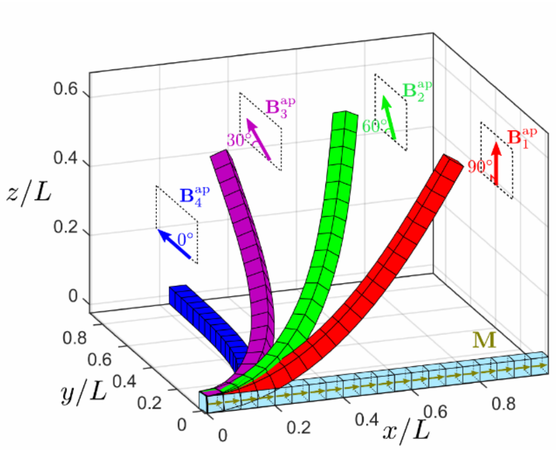

Figure 1. Spatial deformations of a hard-magnetic rod ($L/H = 20.5$ and $W = H$) under different applied magnetic fields $\mathbf{B}^{\mathrm{ap}}$ (in the yz plane). The initial magnetization density $|\mathbf{M}| = 114$ kA/m in the reference configuration is along the x-axis direction. The applied magnetic field $\mathbf{B}^{\mathrm{ap}} = 5$ mT, 10 mT, 30 mT and 50 mT, corresponding to direction $\varphi^{\mathrm{ap}} = 90^\circ, 60^\circ, 30^\circ$ and 0° respectively.

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Acoustic Purcell Effect from Qusibound State in the Continuum

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Abstract: We investigate the acoustic Purcell effect induced by quasi-bound states in the continuum (quasiBICs) both theoretically and experimentally. W demonstrate that the acoustic Purcell factor is governed by the system's radiative and dissipative factors. To improve the upper bound of the Purcell effect, we need to simultaneously decrease the values of both radiative and dissipative factors, which is difficult and even conflicting in realistic acoustic resonant structures. To solve this conflict, we introduce the concept of quasiBIC-induced Purcell effect. QuasiBICs contribute to highly confined acoustic fields and greatly enhanced acoustic emission, leading to a strong Purcell effect. Our concept is demonstrated via a two-cavity system supporting a quasiBIC, which offers tunable and low radiative factors to approach the critical emission condition and promote strong acoustic Purcell effect. With the presented QuasiBIC-supporting system, we experimentally observed strong emission enhancement of the sound source with a Purcell factor of 84.7. Our work bridges the gap between the acoustic Purcell effect and acoustic BICs, essential for enhanced wave-matter interaction and acoustic emission, and may contribute to the research of high-intensity sound sources, high-quality-factor acoustic devices, and nonlinear acoustics.

Noise control for nose landing gear by longitudinal wavy strut

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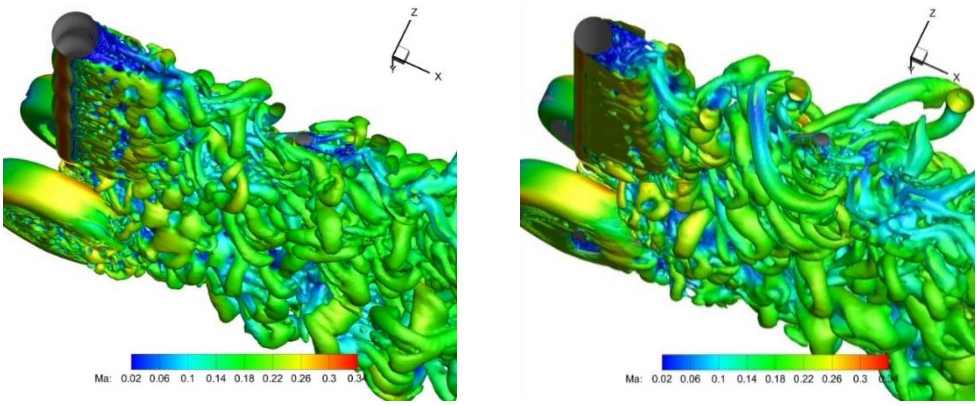
Abstract: Noise pollution of large passenger aircraft has become a hot issue of public concern. The noise of landing gears is a major contributor to the overall airframe noise of an aircraft during approach and landing. Based on the author's previous research work on wavy cylinder, this paper proposes a new noise reduction measure for landing gear with longitudinal wavy strut (LWS). A hybrid aeroacoustics method was used to numerically simulate the flow field and its noise of a low-speed landing gear, while the effects of large-scale longitudinal wave on the strut flow field and noise were also explored. An assessment of the solutions obtained from full landing gear is presented for wavy strut with medium wave height. The numerical simulations have shown that the wavy strut could lead to broadband noise reduction of landing gear noise by up to 2.1dB. Moreover, the underlying noise suppression mechanisms are explored by the process of vorticity generation and evolution of the near wake of wavy strut. The periodic vortex shedding is significantly suppressed in the wake of wavy strut, which might be the main reasons for noise reduction. The distribution of the boundary enstrophy flux (BEF) that are altered in the surface of wavy-strut case also indicate that the wavy strut inhibits the generation of vorticity in the flow field. The distribution of Lamb vector and Helicity in flow field shows the noise reduction mechanism of wavy strut from the perspective of sound source. As expressed by the vortex dynamic processes, this feature implies the landing gear with LWS is of great potential in noise attenuation.



(a) wavy strut (b) circular strut

Figure 1. Comparison of vortex structures by iso-surface of the Q-criterion in (Q =1000) of landing gear with (a) wavy and (b) circular strut

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Application of FBG sensor in deformation monitoring of island-tunnel section of Hong Kong-Zhuhai-Macao Bridge

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Abstract: To capture the deformation patterns of the island-tunnel section, the fiber bragg grating (FBG) sensing technology is adopted to monitor key positions of the tunnel in Hong Kong-Zhuhai-Macao Bridge. As shown in Figure 1, the three-dimensional displacement sensor (TDDS) and the tilt sensor (TS) were developed based on FBG to obtain real-time monitoring data regarding three-dimensional deformation of the tunnel segment and the settlement of the artificial island. The developed TDDS gains a sensitivity of 51.707 pm/mm and an accuracy of 0.099% F.S within the range of -50 mm to 50 mm, while the developed FBG-TS gains a sensitivity of 100 pm/° and an accuracy of 0.099% F.S within the range of -10° to 10°. The preliminary results indicated that the maximum displacement of the tunnel segment occurred longitudinally in the tunnel, and temperature cycles played a crucial role in causing such displacement. Moreover, the settlement curve of the artificial island exhibited symmetrical distributed with respect to the center of the wave wall, with the most significant settlement occurring above the tunnel.

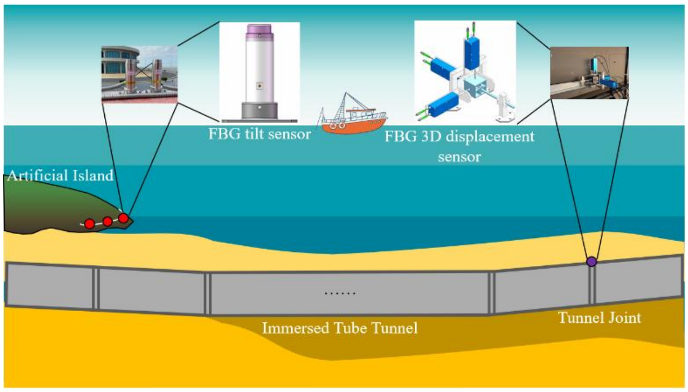

Figure 1. Deformation monitoring network of island-tunnel section of Hong Kong-Zhuhai-Macao bridge based on FBG sensing technology

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Quasilocalized Vibrational Modes as Efficient Heat Carriers in Glasses

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Abstract: It is known that the low-temperature thermodynamic properties such as heat capacity and thermal conductivity in glasses are affected by the low-frequency quasilocalized vibrational modes (QVMs), resulting in a different temperature dependence in crystal solids [1]. These modes originate from the intrinsic disorder of the structure and their thermal energy concentrate on a small group of atoms like the high-frequency localized modes. Unlike delocalized modes, high-frequency localized modes are inefficient heat carriers due to their location [2]. This naturally stimulates a problem. QVMs have similar location as localized modes and are they as inefficient as localized modes?

Here, we distinguish the quasilocalized and delocalized vibrations based on the participation ration (PR) in the three-dimensional binary glass, with the frequency of QVMs lower than the first propagating modes band. The modal thermal transport behaviour is systematically investigated using quasi-harmonic Green-Kubo method. Figure 1a shows that quasilocalized modes are efficient heat carriers, whose modal thermal conductivity (MTC) is similar to that of low-frequency delocalized modes [3]. By decomposing MTC, it is found that the significant thermal transport efficiency of QVMs arise from the important coherence between QVMs and other modes (Figure 2b). Furthermore, the spectral analysis reveals that the strong mutual coherence is resulting from the high mutual energy gain (i.e., high generalized occupation) and the strong mode shape coupling (i.e., high generalized group velocity) between QVMs and their near frequency vibrational modes. This work provides a deeper understanding of thermal transport in glasses.

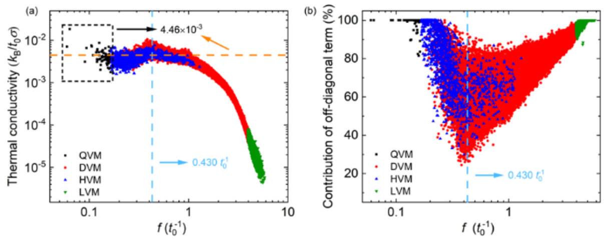

Figure 1. (a) MTC of 512-atom systems for QVMs, DVMs (delocalized modes), HVMs (hybridized modes), and LVMs (localized modes) at 0.163Tg. Averaged MTC of QVMs is 4.46×10^{-3} $k_B/t_0\sigma$. (b) Contribution of off-diagonal term to MTC in (a). The baby blue line is the position of first propagating modes band.

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Development of Two Customized Displacement Measurement Systems

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Abstract: Thanks to the maturity and development of data acquisition technology, people can collect various physical signals, including voltage and current, through data acquisition devices. It is widely used in industrial production, scientific research and other fields. Displacement is one of the most important and fundamental physical quantities in the field of structural health monitoring. Parameter signals that reflect structural characteristics can be extracted from structures for structural damage identification and safety assessment. Therefore, the data acquisition system is the bridge between the hardware equipment and software system of the monitoring system. The signal acquisition technology includes signal acquisition, type of sensors, data acquisition and storage, etc. In this report, two data acquisition systems are designed for laboratory environment, one of them is a LabVIEW-based data acquisition system and the other is a DSCLOG24-based data acquisition system. The composition, acquisition principle and test results of the two systems are introduced respectively. Both systems can realize the functions of real-time monitoring, data storage and data display. The DTU module produced by TASTEK is applied to achieve the purpose of long-distance data transmission with the help of LabVIEW programming.

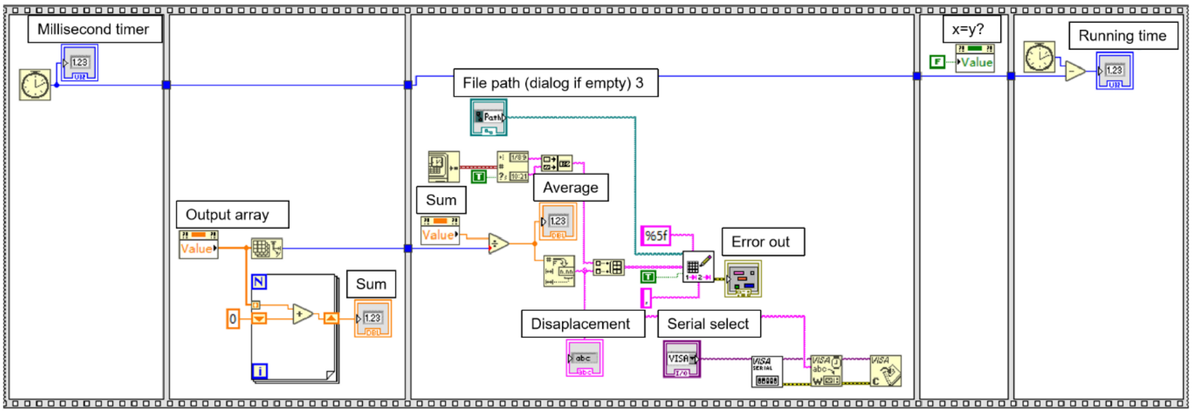

Figure 1. Data processing.

Acknowledgements

The authors greatly acknowledge the financial support from the Science and Technology Development Fund, Macao SAR (Grant No. SKL-IOTSC(UM)-2021-2023) and Guangdong Provincial Department of Science and Technology (Grant No. 2022A0505030019).

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Simulation of Fracture-Pattern Formation in Electrodes during Lithiation/delithiation Cycles

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Abstract: Mechanical failure due to lithium-ion diffusion is one of the main obstacles to fulfill the potential of the electrode materials. Various fracture patterns in different electrode structures are observed in practice, which may have a profound impact on the performance and the service life of electrodes during operation. However, the mechanisms are largely unclear and still lack systematic understanding. Here we propose a coupled chemo-mechanical model based on peridynamics and use it to study the dynamic fracture-pattern formation in electrode materials and solid electrolytes during lithiation/delithiation cycles. We found in hollow core-shell nanowires that geometric parameters such as the size of the nanowire and the thickness of the coating significantly influence the fracture patterns, leading to straight cracks, random crack networks and orthogonal cracks. We also studied fracture-pattern differentiation in film-substrate structures, single crystalline electrodes, solid electrolyte/electrode interfaces, etc. We reveal the mechanisms by investigating the interplay between mechanical stress and lithium-ion insertion/extraction. The results provide insights into the phenomena of dynamic fracture in complex chemo-mechanical environments and the numerical tool is thus useful in guiding the future design of lithium-ion batteries.

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Conference Venues:

The conference will be in The Hong Kong Polytechnic University, Hung Hom, Hong Kong SAR. PolyU campus is well served by MTR. Please exit from MTR Hung Hom Station and follow the sign to access PolyU campus.

The venues for the conference are arranged as follows:

Time	**Event**	**Location**
9am – 12.15pm	Opening Addresses and 5 Distinguished Lectures	GH201
12.15pm – 2pm	Lunch buffet	Area right outside GH201
2pm – 5.15pm	14 parallel sessions	DE301~DE308 & CD304
5.30pm – 5.45pm	Closing Ceremony and Award Presentation	GH201
5.45pm – 6.30pm	HKSTAM Annual General Meeting	GH201
6.30pm	Banquet	Ju Yin House Seafood Restaurant (聚賢樓), 4/F, Communal Building