Proceedings of

The 29th Annual Conference of HKSTAM 2026
The 21st Jiangsu – Hong Kong Forum on Mechanics and Its Applications

18 April 2026

The Hong Kong Polytechnic University, Hong Kong SAR

Editors

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PREFACE

The 29th Annual Conference of HKSTAM 2026 in conjunction with the 21st Jiangsu–Hong Kong Forum on Mechanics and Its Applications is held in The Hong Kong Polytechnic University (PolyU) on 18 April 2026. This conference is co-organized by the Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM), the Jiangsu Society of Theoretical and Applied Mechanics (JSTAM), and PolyU, with sponsorship from Dantec Dynamics. 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 collaborations among relevant parties. This proceeding consists of 80 abstracts, including 13 abstracts from JSTAM, 47 abstracts from HKSTAM, and 20 abstracts from institutions in other regions.

The conference features 4 Distinguished Lectures in the morning that are delivered by Prof. Wei-Hsin LIAO (The Chinese University of Hong Kong), Prof. Xinxing SHAO (Southeast University), Prof. Yang LU (The University of Hong Kong), and Prof. Wei XU (Hohai University). In the afternoon, 10 regular parallel sessions are arranged. Moreover, to encourage interaction among early-career faculty members, this year's conference includes, for the first time, a mini-symposium titled *Young Scholars Forum on Mechanics Across Disciplines: Materials, Biology, Robotics, and Interfaces*, co-organized by Prof. Changhong Linghu and colleagues from the City University of Hong Kong and The Hong Kong University of Science and Technology.

The Society extends its appreciation to all speakers and contributors for their efforts in making this event a success. Special thanks go to Ms. Shushu ZHANG, Secretary of JSTAM, for her significant contributions to the co-organization in Jiangsu, as well as Dr. Xu WANG, Miss Xinyu YANG and other volunteers from PolyU for their assistance in liaising with various parties. The Society also wishes to thank the Institutional Members of HKSTAM for their generous support.

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Conference Program

April 18, Saturday, Morning (Y302)

9:00 – 9:15	**Opening addresses** **MC: Prof. Hui Tang, Secretary of HKSTAM** **Prof. Zhongqing Su (蘇眾慶)** **President of HKSTAM 香港力學學會理事長** **Prof. Dingguo Zhang (章定國)** **Supervisor of JSTAM 江蘇省力學學會監事**
9:15 – 9:50	**Distinguished Lecture I** **Chair: Prof. Dingguo Zhang (章定國)** **Prof. Wei-Hsin Liao (廖維新)** Department of Mechanical & Automation Engineering, The Chinese University of Hong Kong "Vibration, Energy Harvesting, Human Motion"
9:50 – 10:25	**Distinguished Lecture II** **Chair: Prof. Zhongqing Su (蘇眾慶)** **Prof. Xinxing Shao (邵新星)** School of Civil Engineering, Southeast University "Real-time Stereo-DIC for 3D Displacement and Strain Measurement: Methods and Applications"
10:25 – 10:55	**Photo Taking and Tea Break**
10:55 – 11:30	**Distinguished Lecture III** **Chair: Prof. Qingwen Ren (任青文)** **Prof. Yang Lu (陸洋)** Department of Mechanical Engineering, The University of Hong Kong "AI-assisted Design of Multifunctional Mechanical Metamaterials"

11:30 – 12:05	**Distinguished Lecture IV** **Chair: Prof. Hui Tang (唐輝)** **Prof. Wei Xu (徐煒)** Department of Engineering Mechanics, Hohai University "Localization of Debondings in Laminated Panels Using Vibro-Acoustic Modulation Features"
12:05 – 14:00	**Lunch [Grove & Tai Tai Foodtopia, Block Y Outlet]**

April 18, Saturday, Afternoon (Parallel Sessions A1 to C1)

Time	**Session A1 [Y301]** **Solid Mechanics** **Chair: Prof. Xian (Sherry) CHEN**	**Session B1 [Y302]** **Fluid Mechanics** **Chair: Prof. Pingan ZHU**	**Session C1 [Y303]** **Civil Engineering** **Chair: Prof. Qingwen REN**
14:00 – 14:15	Coupled Axial–Shear Bending Model for Multi-Layer Beams Incorporating Timoshenko Effects **Mr. Fei LI** CityU P12	Capillary Effects in Complex Droplet Impact **Prof. Pingan ZHU** CityU P24	Study on the Interface ITZ Thickness Induced by Concrete Hydration Heat Based on Temperature Stress Elasto-Plastic Solution **Prof. Qingwen REN** HHU P37
14:15 – 14:30	Physics-Guided Inverse Design of Bio-inspired Network Metamaterials via a General Non-linear Mechanical Framework for Arbitrary Curved-Beam Lattices **Dr. Shaotong DONG** BHU P13	A Hybrid TENO-NA-CON + THINC Scheme for Simulating Evolving Material Interface Flows within the Quasi-Conservative Framework **Mr. Rongjian SUN** BHU P25	Optical Measurement of Concrete Fracture Interfaces Using Fringe Projection: Methodology, Fracture Morphology, and Durability Mechanisms in Sustainable Concrete **Dr. Meiling DAI** NUS P38
14:30 – 14:45	Million-cycle Reversibility of Superelastic Alloys under Stress-induced Phase Transformation by Special Compatibilities **Mr. Yang LIN** HKUST P14	Numerics and Physics of Bubble Cloud Dynamics **Mr. Haohan HUANG** HKUST P26	Analysis of Forces on Tunnel Linings and the Consequent Uplift Problem **Dr. Chenghao ZHANG** UM P39
14:45 – 15:00	Enhanced Reversibility of Antiferroelectric–Ferroelectric Transition in $PbZr_{1-x}Ti_xO3$ **Ms. Xinyue HUANG** HKUST P15	Theoretical Modeling of Critical Sticking Velocity in Adhesive Particle Collisions Based on the Johnson–Kendall–Roberts Theory **Dr. Zepeng NIU** XAUAT P27	Modeling and Analysis of Frequency-Varying Equivalent Impedance in Vehicle Inertial Suspension Systems **Dr. Changning LIU** JSU P40
15:00 – 15:15	Biaxial Micro-mechanical Device (MMD) with Meta-structure for In Situ Mechanical Testing **Mr. Tiqing ZHAO** HKU P16	The Composite Mean Velocity Profile in Adverse Pressure Gradient and Turbulence Modeling **Dr. Jinrong ZHANG** BHU P28	The Interaction Mechanism of Dam-reservoir-foundation during Impoundment: Case Study of the Xiluodu Project, China **Dr. Linfei ZHANG** ZAFU P41
15:15 – 15:30	-	Improving Condensation Heat Transfer Using Micropillar Surface Topography and Hybrid Wettability **Ms. Nan ZHOU** PolyU P29	A Computational Strategy for Enhanced Nonlinear Structural Stability Analysis in Abaqus **Dr. Jiajia SHEN** University of Exeter P42
15:30 – 16:00	**Tea Break**		

April 18, Saturday, Afternoon (Parallel Sessions D1 to E1)

Time	**Session D1 [Y304]** **AI for Science/Engineering** **Chair: Prof. Hui TANG**	**Session E1 [Y306]** **Multi-disciplinary Coupling** **Chair: Prof. Zhongqing SU**
14:00 – 14:15	Three-dimensional Coherent Structures for Turbulent Flow Estimation in Urban Convective Boundary Layer Using Generative Adversarial Networks **Mr. Lei YAN** HKU P50	Research on the High-speed Water-entry Characteristics of Different Head Projectiles Based on Two-way Fluid-Structure Interaction **Mr. Jianwei HAN** NJUST P62
14:15 – 14:30	A Multi-scale Topology Optimization Framework for High-performance TPMS Based Piezoelectric Metamaterials via Deep Learning Surrogate Models **Mr. Chang LIU** BHU P51	Quantifying the Role of Thermoelectric Magnetohydrodynamic Process in Keyhole Pore Formation during Laser Powder Bed Fusion **Mr. Yibo MA** HKUST P63
14:30 – 14:45	Efficient Optimization of High-dimensional Engineering Problems **Ms. Xinyu YANG** PolyU P52	Study on the Acoustic Propagation in Impact Ice Based on Biot Theory **Ms. Yang ZHANG** NUAA P64
14:45 – 15:00	Trajectory Control for Obstacle Avoidance of Flexible Manipulators Based on Spatio-Temporal Attention **Mr. Junwei CHEN** NJUST P53	Experimental Study of Fabric Evolution during Multiple Liquefaction of Toyoura Sand **Mr. Chengxin CHU** HKUST P65
15:00 – 15:15	Reconstructing High-resolution Tidal Fields from Sparse Sensor Data Using a Pretrained Spatiotemporal Generative Model **Mr. Yuxuan XIA** HKUST P54	Oxidation-induced Crack Initiation and Propagation Behaviors of Ni-based Single Crystal Superalloy in VHCF Regime **Mr. Yang MENG** BHU P66
15:15 – 15:30	-	-
15:30 – 16:00	**Tea Break**	

April 18, Saturday, Afternoon (Parallel Session A2 to C2)

Time	Session A2 [Y301] Solid Mechanics Chair: Dr. Wendong HUO	Session B2 [Y302] Fluid Mechanics Chair: Dr. Jingxin WANG	Session C2 [Y303] Civil Engineering Chair: Prof. Jun YANG
16:00 – 16:15	Explicit Structural Optimization for Thin-walled Structures with Complex Surfaces **Dr. Wendong HUO** HKU P18	Deformation and Breakup of Water Droplet in Shear Airflow **Dr. Jingxin WANG** NUAA P31	An Experimental Study of Cyclic Strength and Stiffness Degradation of Sand with Clayey Fines **Mr. Liheng TANG** HKU P44
16:15 – 16:30	Effect of Sample Thickness on Buckling Characteristics and Mechanical Performance of Liquid Crystal Elastomers **Mr. Zelong WANG** HKUST P19	An Improved Baldwin-Lomax Model for Complex Hypersonic Flows **Mr. Jian SHEN** HKUST P32	Evolution of Unloading–Reloading Moduli in Sand: New Findings and Interpretations **Mr. Zhi LIU** HKU P45
16:30 – 16:45	Theoretical Analysis of Inflated Tube Wrinkling Behavior under Pure Bending **Ms. Wenbin WU** BHU P20	Dynamic Modeling of Microrobot–vessel Collision within a 3D Flexible Vascular System for Thrombus Removal **Mr. Fengzhu WANG** XAUAT P33	Rainfall Infiltration Boundary for Unsaturated Soil Slope by Single-Point Two-Phase Material Point Method **Mr. Aohan QIN** HKUST P46
16:45 – 17:00	Synergizing Low Dielectric Constant with Robust Mechanical and Thermal Properties in Dual-Phase Amorphous Boron Nitride Interconnects **Mr. Binzhao LI** CityU P21	An Integrated Experimental and Computational Platform for Assessing Microclimate of Sports Footwear **Mr. Junyan SHEN** PolyU P34	Soil Surface Erosion Simulation Using Material Point Method **Mr. Hang FENG** PolyU P47
17:00 – 17:15	Compositionally Tuned Enhancement of Phase Transformation Compatibility in Pyroelectric Energy-Harvesting Materials **Mr. Ruiheng GENG** HKUST P22	Curvature Correction Effects on Airfoil Separated Flows at High Angles of Attack **Ms. Ruijie BAI** BHU P35	Achromatic Acoustic Meta-Lens for High-Capacity Underwater Communication Through Acoustic Barriers **Ms. Ming MA** PolyU P48

April 18, Saturday, Afternoon (Parallel Sessions D2 to E2)

Time	**Session D2 [Y304]** **AI for Science/Engineering** **Chair: Prof. Mengze WANG**	**Session E2 [Y306]** **Precision Instrument** **Chair: Dr. Bicong WANG**
16:00 – 16:15	Taming the Chaos: A Non-intrusive Machine-learning Framework for Debiasing Climate Emulations and Quantifying Rare Event Statistics **Prof. Mengze WANG** CityU P57	Diamond-Based 3D Rotation Sensing for Force Measurement **Dr. Bicong WANG** HKU P68
16:15 – 16:30	Method for Identifying Vortex-Induced Vibration Anomalies in Transmission Tower Components Based on Machine Vision **Dr. Wenkang DU** SEU P58	A Modular, Bubble-infused Hydrogel Wearable Ultrasound Device for Minimally Invasive Biochemical Monitoring **Mr. Qi YUAN** PolyU P69
16:30 – 16:45	Research on and Modification of Turbulence Models for Adverse Pressure Gradients Based on Symbolic Regression **Dr. Hanqi SONG** BHU P59	The Infiltration Paradox: How Pore-gas Pressure Controls Early Slope Failure under Rapid Surface Hydraulic Loading **Ms. Xiaoying CHEN** HKUST P70
16:45 – 17:00	Ultrasonic Measurement of Ice Layer Melting on the Surface of Aircraft Skin **Dr. Yuan WANG** NUAA P60	In Situ Ice Monitoring on Aircraft Wings Using a Flexible Ultrasonic Transducer **Mr. Yan WANG** NUAA P71
17:00 – 17:15	–	A Strain-insensitive Dual-stopband Flexible 3D FSS for Stable Electromagnetic Performance under Mechanical Stretching **Mr. Kuan WANG** BHU P72

April 18, Saturday, Morning (Young Scholars Forum on Mechanics Across Disciplines: Materials, Biology, Robotics, and Interfaces)

Time	**Session F1 [Y301]** **Young Scholars Forum** **Chair: Prof. Changhong LINGHU**
10:50 –11:00	**Opening** **Prof. Changhong LINGHU** CityU
11:00 – 11:15	Structural Designs, Mechanics and Multi-functional Applications of Advanced Multi-scale Composites **Prof. Chao WANG** HIT P74
11:15 – 11:30	Topological Defects Mediate Transport Phenomena in Active Soft Solids **Prof. Rui ZHANG** HKUST P75
11:30 – 11:45	Strain Gradient Mediated Decoupling of Thermal Conductivity and Anisotropy in Bent Ga2O3 **Prof. Qiye ZHENG** HKUST P76
11:45 – 12:00	Vibration-coded Metamaterials for Intelligent Predictive Maintenance of Low-altitude Aircraft **Dr. Chong LI** HKU P77
12:15 – 14:00	**Lunch** **[Grove & Tai Tai Foodtopia, Block Y Outlet]**

April 18, Saturday, Afternoon (Young Scholars Forum on Mechanics Across Disciplines: Materials, Biology, Robotics, and Interfaces)

Time	Session F2 [TU101] **Young Scholars Forum** Chair: Prof. Tianju XUE	Time	Session F3 [TU101] **Young Scholars Forum** Chair: Prof. Lin FU
14:00 – 15:15	Ultrathin Seed Wing with Heterogeneous Structure for Highly Efficient Dispersal of African Tulip Tree **Prof. Jianing WU** SYSU P79	15:45 – 16:00	Modeling the History Dependent Behavior of Viscoelastic Composites Using Recurrent Neural Operator **Prof. Sheng MAO** PKU P86
14:15 – 14:30	Shape Memory Polymer-based Switchable Bio-inspired Microstructured Dry Adhesives **Dr. Qingsong HE** NUAA P80	16:00 – 16:15	Rationalizing Polymer Networks with Hyperelasticity and Omniadhesion **Prof. Canhui YANG** SUSTech P87
14:30 – 14:45	Spinning Twisted Ribbons: When Two Holes Meet on a Curved Liquid Film **Prof. Jack Hau Yung LO** CityU P81	16:15 – 16:30	Reconfigurable Nano-kirigami Surfaces: Multiscale Mechanics Modeling and Application in Optical Sensing of Environmental and Health Hazards **Prof. Huifeng DU** PolyU P88
14:45 – 15:00	Synthesis-property Relation of Soft Materials **Dr. Yecheng WANG** SYSU P82	16:30 – 16:45	An LSTM-FEA Integrated Approach to Predict Curing-Induced Deformation in Woven Thermoset Composite **Prof. Weizhao ZHANG** CUHK P89
15:00 – 15:15	Fourier Reduced Physics Informed Neural Operator for Solving Parametric PDEs in Computational Mechanics **Dr. Yifan XIA** ZJU P83	16:45 – 17:00	Modeling and Prediction of Hypersonic Wall Turbulence **Prof. Lin FU** HKUST P90
15:15 – 15:30	Style-constrained Inverse Design of Microstructures with Tailored Mechanical Properties Using Unconditional Diffusion Models **Prof. Tianju XUE** HKUST P84	17:00 – 17:15	Intrinsic Interfacial Shear Characterization via Coupled Shear-Lag Model and PINN Inversion **Dr. Yafei YIN** HKU P91
15:30 – 15:45	**Tea Break**	17:15 – 17:30	Long-term Adhesion Durability Revealed through a Rheological Paradigm **Dr. Rui WU** CityU P92

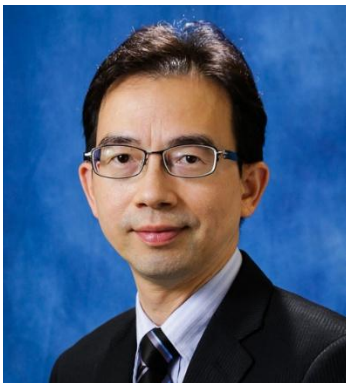
April 18, Saturday, Evening

17:30 – 17:45	**Closing Ceremony and Award Presentation [Y302]**
17:45 – 18:15	**HKSTAM Annual General Meeting [Y302]** Attendees: Representatives of all Institution Members and all Full HKSTAM members
18:30	**Banquet [Ju Yin House Seafood Restaurant (聚賢樓), 4/F, Communal Building, PolyU]**

~ Closure of the conference ~

Distinguished Lectures

Distinguished Lecture I



Prof. Wei-Hsin Liao (廖維新)

Wei-Hsin Liao received his Ph.D. in Mechanical Engineering from The Pennsylvania State University, University Park, USA. Since August 1997, Dr. Liao has been with The Chinese University of Hong Kong, where he is currently Choh-Ming Li Professor of Mechanical and Automation Engineering, and Director of the Institute of Intelligent Design and Manufacturing. His research has resulted in the publication of over 450 technical papers and 30 patents, including nine journal papers that received Best Paper or Top Cited Paper Awards from ASME, IMechE and IOP Publishing. He was the Conference Chair for the 20th International Conference on Adaptive Structures and Technologies in 2009; the Active and Passive Smart Structures and Integrated Systems, SPIE Smart Structures/NDE in 2014 and 2015. He is the recipient of the 2020 ASME *Adaptive Structures and Material Systems Award* and the 2018 SPIE *SSM Lifetime Achievement Award*, to recognize his outstanding contributions to the advancement of smart structures and materials. He also received the 2023 *ASME Leonardo Da Vinci Award* for eminent achievement in machine design. Dr. Liao currently serves as an Associate Editor for *Journal of Intelligent Material Systems and Structures*, and on the Executive Editorial Board of *Smart Materials and Structures*. He is a Fellow of the American Society of Mechanical Engineers (ASME), the Institute of Physics (IOP), and The Hong Kong Institution of Engineers (HKIE).

Vibration, Energy Harvesting, Human Motion

Wei-Hsin Liao
Department of Mechanical & Automation Engineering, The Chinese University of Hong Kong

By utilizing adaptive features, smart materials can be developed as actuators and sensors, serving as intelligent elements for vibration control in structures. On the other hand, energy can be harvested from vibrations and human motion. Piezoelectric and electromagnetic power generators are used to convert mechanical energy from these sources into electrical energy. An energy flow was proposed, accompanied by detailed analysis to clarify and illustrate each branch of energy flow in piezoelectric energy harvesting systems. Given the substantial amount of kinetic energy generated by the human body during physical activities, capturing human motion and converting it into electricity presents promising prospects for sustainably powering wearable devices and meeting the continuous operation requirements of IoT applications. To scavenge the kinetic energy from human joints, various energy harvesters have been designed and investigated. Furthermore, robotic exoskeletons and smart ankle-foot prostheses have been developed to assist individuals with impaired mobility. Related work will be presented.

Distinguished Lecture II

Prof. Xinxing Shao (邵新星)

Xinxing Shao received his BS degree in engineering mechanics from Southeast University, China, in 2012 and PhD in experimental solid mechanics from Southeast University, China, in 2018. He held visiting appointments at University of Science and Technology of China, Singapore University of Technology and Design, University of Toronto and Purdue University. Currently, he is an associate professor in the School of Civil Engineering at Southeast University. His current works are focus on real-time, high-resolution and fully automatic deformation measurement and development of scientific instruments. He is a reviewer for more than 50 international journals and has authored more than 80 peer-reviewed publications in the field of optical deformation measurement with over 2200 citations. Now, He is the Deputy leader of Optical Measurement Group in CSTAM. He is the member of SEM, SPIE and Optica (formerly OSA).

Real-time stereo-DIC for 3D displacement and strain measurement: methods and applications

Xinxing Shao*#
School of Civil Engineering, Southeast University, Nanjing, China

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Presenter: xinxing.shao@seu.edu.cn

With the recent increase in mechanics and engineering applications, it is important to improve the computational efficiency of full-field deformation measurement and realize the closed loop control of systems. A real-time three-dimensional (3D) digital image correlation (DIC) method for displacement and strain measurements is proposed in this paper. To solve the problem of initial guess estimation under large deformation and rotation, a temporal-spatial deformation transfer scheme is proposed for efficient temporal and stereo matching in 3D-DIC. The highly efficient IC-GN algorithm with an improved interpolation look-up table is proposed to further improve the computational efficiency. The multipoint and full-field real-time 3D deformation measurements are performed by parallel computation. Benefiting from the temporal-spatial deformation transfer scheme, the efficient IC-GN algorithm, the efficient temporal and stereo matching strategy and the parallel computation, real-time multipoint deformation measurements at 150 Hz with 50 points and full-field deformation measurements at 10 Hz with 10000 points are realized. The latest advances in improving the accuracy and efficiency of deformation measurement using deep learning are also presented.

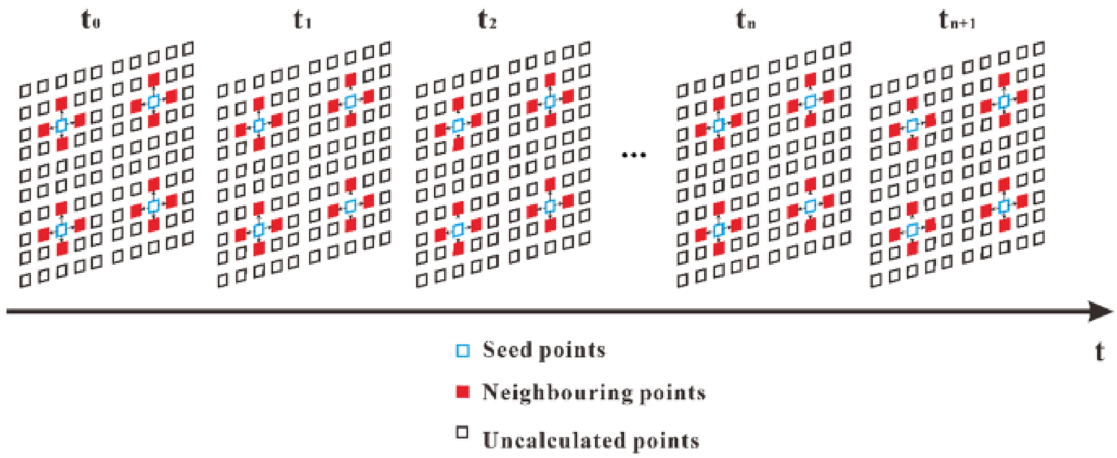

Figure 1. Temporal-spatial deformation transfer with multiple seed points.

Acknowledgements
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Distinguished Lecture III

Prof. Yang Lu (陸洋)

Yang Lu, Associate Dean of Engineering, Chair Professor of Nanomechanics, Kingboard Professor in Materials Engineering and HKU-100 Scholar at The University of Hong Kong. He received his BS degree in Physics from Nanjing University and PhD degree in Mechanical Engineering from Rice University, and did his postdoctoral research in the Nanomechanics Lab at MIT. Previously, he worked at City University of Hong Kong as Assistant Professor, Associate Professor and Full Professor during 2012 to 2021. His main research areas include micro/nano mechanics and advanced manufacturing. He has made significant contributions to the discovery of phenomena such as cold welding of nanoscale metals and ultra-large elasticity of silicon and diamond at the nanoscale. He is dedicated to the research of new metal micro-lattice materials such as medium/high-entropy alloys, which promote a new paradigm shift in high-performance structural design and advanced manufacturing, providing new inspiration for the development of lightweight and high-strength aerospace materials. He has published more than 200 articles in leading academic journals including Science, Nature Nanotechnology, Nature Materials, Nature Communications and Science Advances. Professor Lu serves as an associate editor for the international journal Materials Today, as well as a board member for academic journals such as National Science Review, Science China Technological Sciences, and Acta Mechanica Sinica. Prof. Lu is a recipient of UGC Early Career Award 2013/14, the NSFC Young Scientists Fund Type B in 2019 and Type A in 2025, and RGC Research Fellow scheme (RFS) 2020/21. He is an elected member of the Hong Kong Young Academy of Sciences (YASHK) in 2022, and elected fellow of Hong Kong Academy of Engineering (Young Member Section) in 2025.

AI-assisted Design of Multifunctional Mechanical Metamaterials

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The vast design space of mechanical metamaterials presents a challenge for traditional heuristic approaches, yet offers nearly infinite possibilities for high-performance structural and novel multifunctional design. Here, we propose a machine learning (ML)-driven framework to bridge the gap between material composition and geometric topology optimization. Building upon our previous research on metal microlattices, we leveraged deep learning algorithms to guide the fabrication of a high-strength and ductile carbon lattice mechanical metamaterial through the predictive optimization of partial pyrolysis parameters of 3D-printed polymer microlattices. By employing inverse design algorithms to tailor the lattice architecture for specific semiconductor coating interfaces, we assembled multifunctional devices with superior performance. Specifically, utilizing multi-objective topology optimization to maximize thermal impedance while maintaining structural integrity, we manufactured three-dimensional thermoelectric generators that demonstrate an energy absorption of approximately 30 J/g and a power conversion efficiency of about 10%. Furthermore, through the data-driven design of nanocomposite precursors and high-precision micro/nano 3D printing, we created high-performance transparent glass microlattices, which can be further extended to semiconductor metamaterials. In conclusion, intelligent multifunctional mechanical metamaterials are driving a new paradigm shift in AI-enabled structural design and advanced manufacturing.

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Distinguished Lecture IV

Prof. Wei Xu (徐煒)

Dr. Wei Xu is an Associate Professor affiliated with Department of Engineering Mechanics at Hohai University (HHU), P.R. China. Before joining HHU he was a Postdoctoral Research Fellow at Department of Mechanical Engineering of the Hong Kong Polytechnic University (PolyU) under the “Hong Kong Scholars Program”. Prior to this, he earned his Ph.D. (2016) and BEng (2010) from HHU. His research interests lie primarily in the area of composites, smart structures, vibration, waves, and non-contact measurements with their applications in structural health monitoring. He was awarded the “Dragon-STAR Innovation Award” by the European Commission in 2015, the “Hong Kong Scholars Award” by the Ministry of Human Resources and Social Security (P.R. China) in 2019, and the “Natural Science Award” twice by the Ministry of Education (P.R. China) in 2016 and 2021. He was nominated the 2021 Emerging Leader Award by IOP and awarded the 2022 Best Paper Award by ASME.

Localization of Debondings in Laminated Panels Using Vibro-Acoustic Modulation Features

W. Xu[*#1,2], Y. Yang[1], G. Li[1], M. Cao[1], M. Radzieński[2] and W. Ostachowicz[2]
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[2]Institute of Fluid-Flow Machinery, Polish Academy of Sciences, Gdańsk, Poland

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#Presenter: wxu@hhu.edu.cn

Laminated structures are susceptible to hidden interfacial damage, such as debonding, which can critically undermine structural integrity. The early detection of these defects, particularly when they are barely visible, remains a significant challenge for conventional vibration-based methods. This study addresses this gap by introducing and experimentally validating a nonlinearity-sensitive approach for localizing barely visible debondings. A model of interfacial contact forces is proposed in which nonlinear interface forces associated with sideband spectral components, termed sideband interface forces (SIFs), are generated via vibro-acoustic modulation (VAM). A key attribute of the SIFs is their spatial confinement to the debonding region, where they act as a local multi-tone source that produces sideband harmonics. This study focuses on mapping these interfacial VAM features to create a direct pathway for precise debonding localization. Specifically, the spatial distribution of SIFs is statistically reconstructed from operating deflection shapes spectrally associated with sideband harmonics measured using scanning laser vibrometry, serving as a spatial indicator of the debonding's location and span. The efficacy of the approach is demonstrated through experiments on a laminated panel containing a barely visible debonding. Results reveal that these interfacial vibro-acoustic modulation features successfully localize a debonding measuring just 0.12 mm in thickness. The approach is then extended to a composite laminated plate with multiple delaminations, where experimental results show that, beyond three large thermal delaminations, several small delaminations induced by the Teflon inserts and impacts can also be graphically characterized.

Acknowledgements

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Parallel Session A1

Bulk Spinodal-Architected Compositionally Complex Alloy with Ultrahigh Energy Absorption across a Wide Temperature Range

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Bulk mechanical energy-absorbing materials are critically needed for various engineering applications. However, existing state-of-the-art materials face significant limitations: architected systems such as 3D-printed nano- and micro-lattices suffer from scalability constraints, while conventional foams often exhibit a strength-ductility trade-off that limits energy absorption. Here, we overcome these challenges by fabricating bulk architected alloys via electrochemical dealloying of a machine learning-identified compositionally complex spinodal alloy. These materials display a hierarchical structural architecture spanning seven orders of magnitude – from atomic-scale lattice distortion, nanoscale precipitates and amorphous oxide layers, microscale ligaments, to macroscale network dimensions. This multi-scale integration enables synergistic deformation mechanisms, yielding unprecedented energy absorption capacities of ~106 MJ/m^3 in bulk and ~305 MJ/m^3 in micro-samples. Remarkably, this ultrahigh performance is retained from room temperature to 873 K, surpassing all known energy-absorption materials to date. Our approach provides a transformative strategy for designing scalable, high-performance architected materials for extreme-condition energy absorption.

Coupled Axial – Shear Bending Model for Multi-Layer Beams Incorporating Timoshenko Effects

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Multi-layer beam structures widely arise in composite laminates, bio-inspired layered materials, and structural components composed of alternating soft-hard phases. Their bending behavior is governed by complex interactions between axial deformation, interlayer shear transfer, and layer-wise geometric compatibility. Accurate modeling of such systems is essential for understanding stiffness evolution and size-dependent effects in layered structures.

The deformed tension-shear chain framework assumes axial load transfer in the stiff phase and shear transfer in the compliant phase, neglecting shear deformation within the stiff layer. For finite layer thickness or moderate stiffness contrast, shear deformation in the stiff phase may contribute to bending behavior.

In the present work, an extended formulation is developed by introducing a shear-related rotational variable for each stiff layer within the tension-shear framework. The rotation of each layer is decomposed into an Euler-Bernoulli bending component and a shear-induced correction, leading to intrinsic axial-shear coupling. Based on layer-wise compatibility and equilibrium, the governing equations are derived as a linear system of second-order ODEs:

$$U'' = AU + B\alpha + b, \qquad \alpha'' = CU + D\alpha + d,$$

where U denotes layer-wise axial displacements, α represents shear-induced rotations of the hard layer, and A,B,C,D are constant coefficient matrices determined by material and geometric parameters. The system is linear and non-homogeneous due to bending-induced forcing.

Although closed-form analytical solutions are generally difficult for multi-layer systems, the intrinsic structural characteristics are governed by the associated homogeneous equations. By recasting the system into the compact matrix form

$$Y'' = KY + f,$$

the constant matrix K captures axial–shear coupling and interlayer interaction. The eigenvalues of K characterize intrinsic coupling length scales governing the relative contribution of axial and shear deformation in the bending response of multi-layer beams.

The proposed formulation provides a generalized theoretical framework for layered beams incorporating Timoshenko-type shear effects and forms a basis for subsequent investigations of size dependence and interfacial behavior.

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Physics-Guided Inverse Design of Bio-inspired Network Metamaterials via a General Non-linear Mechanical Framework for Arbitrary Curved-Beam Lattices

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Biological soft tissues achieve a remarkable balance of compliance, toughness, and durability through their hierarchical fibrillar architectures, exhibiting nonlinear mechanical responses like the characteristic J-shaped stress–strain curve. Inspired by these natural designs, periodic network metamaterials composed of curved beam elements hold immense potential for soft robotics, bio-integrated electronics, and tissue engineering. However, rational design remains hindered by prevailing theoretical models, which are typically restricted to specific, idealized geometries and fail to accurately capture essential multiscale deformation mechanisms. To overcome these limitations, we present a generalized nonlinear mechanical framework to characterize periodic networks of arbitrarily shaped curved beams. By systematically bridging individual beam mechanics with lattice-level interactions under finite extension, this framework accurately predicts complex nonlinear responses. Its predictive capability is substantiated by extensive finite element simulations and experimental validation. Building upon this physically grounded foundation, we introduce an efficient inverse design methodology to precisely tailor network architectures toward targeted mechanical specifications. Unlike opaque data-driven paradigms reliant on extensive training datasets, this approach combines computational efficiency with transparent physical interpretability. Collectively, this work establishes a robust theoretical framework and practical design paradigm for optimizing bio-inspired soft network metamaterials.

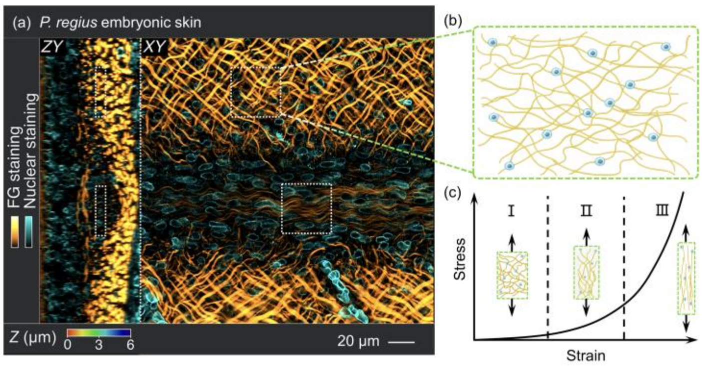

Figure 1. (a) Confocal microscopic images of *P. regius* embryonic skin showing fibrillar architectures, with fibers stained orange and nuclei stained cyan. (b) Schematic representation of the fibrillar network, highlighting wavy fiber organization interspersed with nuclei. (c) Typical J-shaped stress–strain curve of biological tissue with fiber morphologies at different deformation stages.

Acknowledgements

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Million-cycle Reversibility of Superelastic Alloys under Stress-induced Phase Transformation by Special Compatibilities

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Superelastic alloys are widely used in industry but often suffer from limited functional reversibility. In this talk, we propose two compatibility mechanisms ensuring million-cycle reversibility of superelastic alloys under stress-induced martensite phase transition, namely, (i) minimization of transformation shear and (ii) near satisfaction of the cofactor condition. Specific kinematic compatibility conditions between austenite and martensite are strongly correlated with enhanced cyclic stability. We demonstrate these mechanisms in $Ni_{50}Mn_{31.75}Ti_{18.25}$ Heusler and $Ti_{50.8}Ni_{34.2}Cu_{12.5}Co_{2.5}$ alloy systems. In the $Ni_{50}Mn_{31.75}Ti_{18.25}$ Heusler alloy system, along [001] crystallographic orientation, the shear of martensite twin relative to austenite is minimized, with a value of 0.001 (~0.05°). The minimized shear suppresses slip activation, thereby enabling millions of cyclic lifetimes. In the $Ti_{50.8}Ni_{34.2}Cu_{12.5}Co_{2.5}$ superelastic alloy system, near satisfaction of the cofactor condition leads to a broader class of microstructures and marginal transition layers. This allows the material to readily accommodate existing defects and inhibits the nucleation of new ones. Our findings open a new potential material design strategy for controllable superelastic behavior and superior fatigue-resistant shape memory alloys.

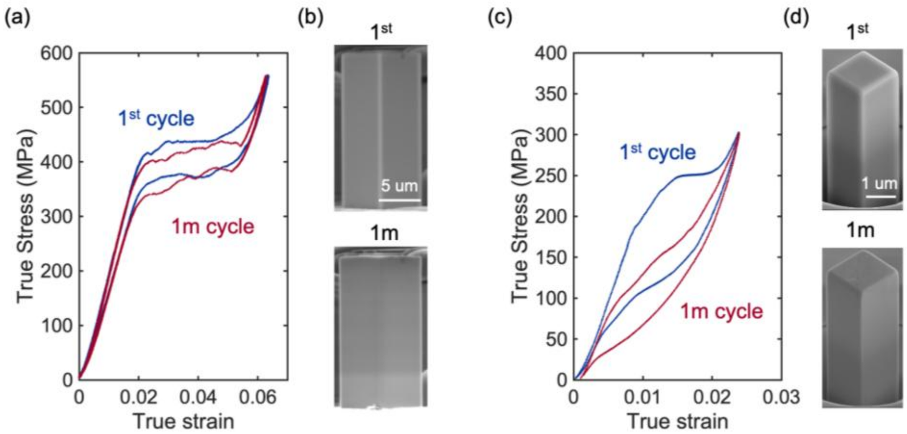

Figure 1. Uniaxial compression superelasticity and cyclic reversibility of $Ni_{50}Mn_{31.75}Ti_{18.25}$ and $Ti_{50.8}Ni_{34.2}Cu_{12.5}Co_{2.5}$ micropillars. (a, d) Exceptional reversibility of micropillars with no detectable cracking or structural degradation after one million cycles under (b, d) SEM of [001] orientated $Ni_{50}Mn_{31.75}Ti_{18.25}$ and $Ti_{50.8}Ni_{34.2}Cu_{12.5}Co_{2.5}$ micropillars, respectively.

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Enhanced Reversibility of Antiferroelectric–Ferroelectric Transition in $PbZr_{1-x}Ti_xO3$

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The $PbZr_{1-x}Ti_xO3$ (PZT) system is a cornerstone material in multifunctional ceramics, renowned for its outstanding piezoelectric, ferroelectric, and dielectric properties. These characteristics have enabled its extensive application in sensors, actuators, transducers, and, more recently, hig[ii]h-energy-density storage devices. This study focuses on enhancing energy storage functionality by leveraging the antiferroelectric (AFE) behavior of PZT ceramics. Differential Scanning Calorimetry (DSC) reveals that the thermal hysteresis of the AFE-to-ferroelectric (FE) phase transformation varies with Ti composition. Systematic X-ray diffraction (XRD) analysis indicates a rhombohedral-to-orthorhombic transition, which deviates from conventional group–subgroup symmetry relationships and is typically considered irreversible. However, lattice parameter extraction from powder diffraction data shows that the transition can become reversible when mediated by a stable rhombohedral phase satisfying geometric compatibility conditions. Theoretical modeling of transformation pathways and compatibility criteria identifies the Ti composition x = 0.005 as optimal, exhibiting low thermal hysteresis and satisfying compatibility conditions. Electron Backscatter Diffraction (EBSD) was employed to characterize grain morphology and orientation, guiding Focused Ion Beam (FIB) fabrication of micropillars for compositions x = 0.005 and x = 0.03. High-temperature uniaxial compression cycling experiments confirmed enhanced mechanical reversibility at x = 0.005, validating the theoretical predictions. These findings establish phase compatibility as a guiding principle for designing reversible AFE–FE switching in functional oxide materials.

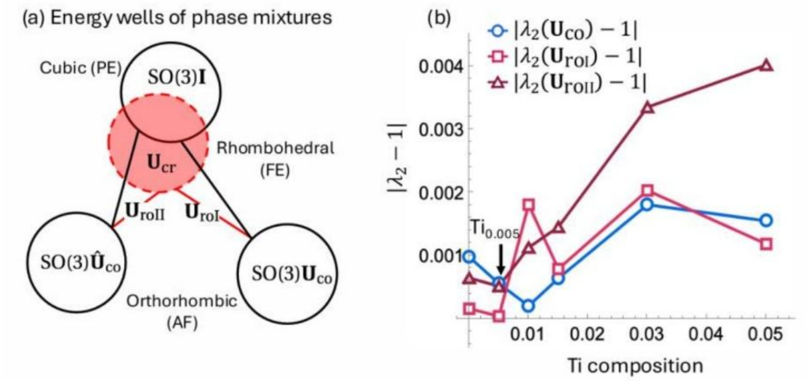

Figure 5. (a) Illustration of the energy wells for the phase transformation among cubic, rhombohedral and orthorhombic symmetries. (b) Assessment of compatibility for cubic to orthorhombic, and rhombohedral to orthorhombic transformations via two pathways.

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Biaxial micro-mechanical device (MMD) with meta-structure for *in situ* mechanical testing

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Low-dimensional materials are crucial for next-generation electronic systems but their size-dependent mechanical properties demand precise *in situ* mechanical characterization. This study aims to develop a novel and stable micro-mechanical device (MMD) device with excellent load-displacement linearity, utilizing cost-effective fabrication method, and to investigate the biaxial tensile behavior of low-dimensional materials. We designed a MMD with a meta-structure of chiral patterns, fabricated using standard silicon wafers and wet etching, which reduces production costs and enables batch manufacturing, and did the uniaxial and biaxial tensile test. This design reduces stretching stress, enhancing stability, load-displacement linearity, and experimental repeatability. This MMD provides a cost-effective solution and tailorable platform for *in situ* mechanical characterization of low-dimensional materials, with the capability of biaxial stretching.

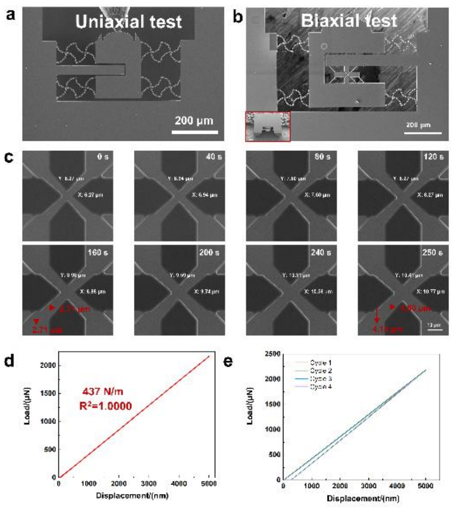

Figure 1.Mechanical test of the biaxial stretching device.

Acknowledgements

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Parallel Session A2

Explicit Structural Optimization for Thin-walled Structures of Complex Surfaces

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Thin-walled structures are widely employed in major industrial equipment due to their high efficiency. Their design and optimization are of great importance for reducing equipment costs, improving performance, and increasing material utilization. As a result, structural optimization of thin-walled structures has long been a key topic in industrial equipment development. However, the complex surface geometries of such structures make it difficult to directly apply conventional structural optimization methods.
This report provides a brief overview of the first author's doctoral research on the design and optimization of thin-walled structures. By incorporating conformal parameterization, surface cutting, and multi-patch stitching to handle complex geometries, and by employing the explicit Moving Morphable Components (MMC) method for material layout description and optimization, a research framework based on "mapping from surface and designing in planar domain" was developed. Within this framework, a series of studies was conducted to address different engineering demands.

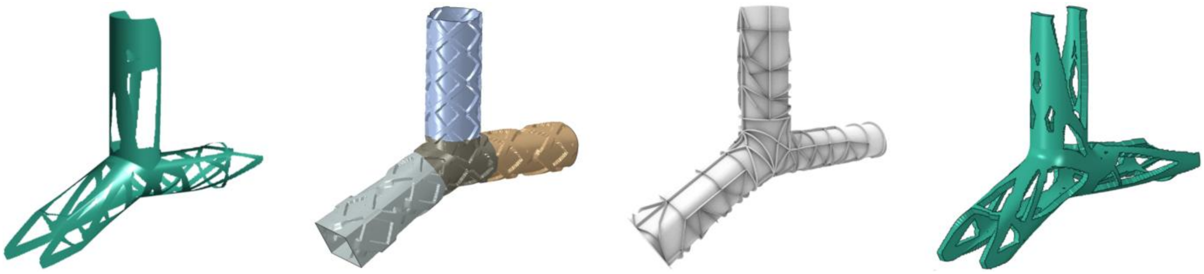

Figure 1. A quick glance of this report.

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Effect of Sample Thickness on Buckling Characteristics and Mechanical Performance of Liquid Crystal Elastomers

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Liquid crystal elastomer (LCE), which has potential application for artificial muscle and soft robotics, has attracted wide attention from researchers, mainly because it exhibits several remarkable properties such as strong deformability and reversible deformation under certain conditions. Prior study has primarily investigated the mechanics and microstructure of surface instabilities in LCE. In our research, we focus on establishing and experimentally verifying the relationship between sample thickness and microstructure. We fabricated LCE samples with different thicknesses and conducted surface instability and tensile experiment. It is demonstrated that the buckling period size increases linearly with sample thickness. In addition, mechanical properties of these samples were parameterized and analysed.

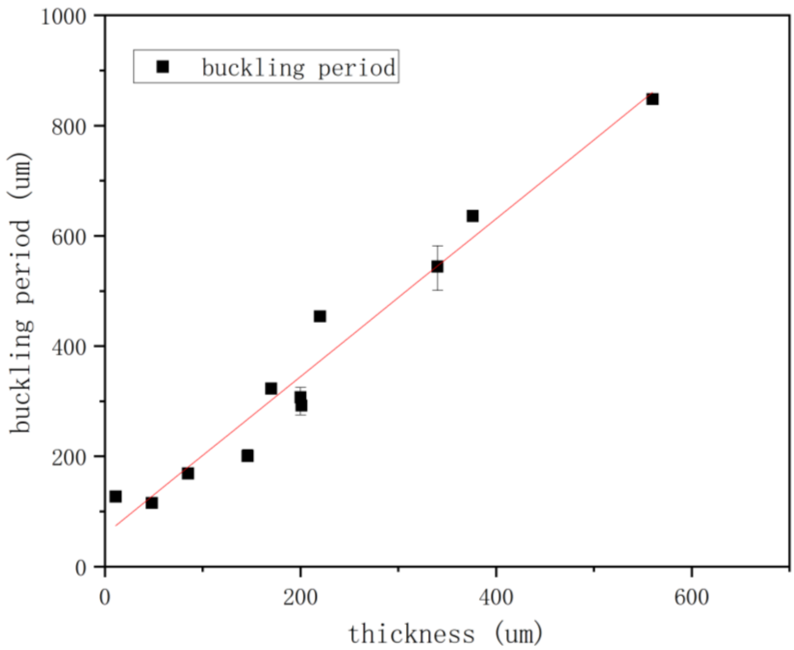

Figure 1. Thickness-buckling period statistic results and their linear fitting.

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Theoretical analysis of inflated tube wrinkling behavior under pure bending

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Inflatable tubes, owing to their lightweight and foldable characteristics, have important applications in soft robots and space expandable structures. The application of a bending load to the inflated tube might induce local instability on its compressed side, leading to the formation of wrinkles that could potentially compromise the structural strength. Therefore, it is necessary to have a comprehensive understanding of the wrinkling behavior exhibited by inflated tubes under bending load. Initially, a theoretical solution is developed for the critical wrinkling behavior of inflated tubes under pure bending, drawing upon the principle of minimum potential energy. According to the energy expression of the system, the critical wrinkling behavior of inflated tubes depends on dimensionless geometrical and internal pressure parameters. The critical wrinkling load and wrinkle pattern of the system are influenced by the thickness-radius ratios and the ratio of internal air pressure to Young's modulus. Subsequently, the theoretical solutions are validated through several finite element analysis examples and a systematic investigation is conducted into the influence of dimensionless geometrical and internal pressure parameters. Finally, the evolution of morphology in post-buckling is investigated through numerical results. The findings suggest that during post-buckling, the wrinkles may undergo a secondary bifurcation and evolve into a non-axisymmetric diamond-like pattern. These results hold significant implications for understanding the bending instability and failure mechanisms of inflated tubes.

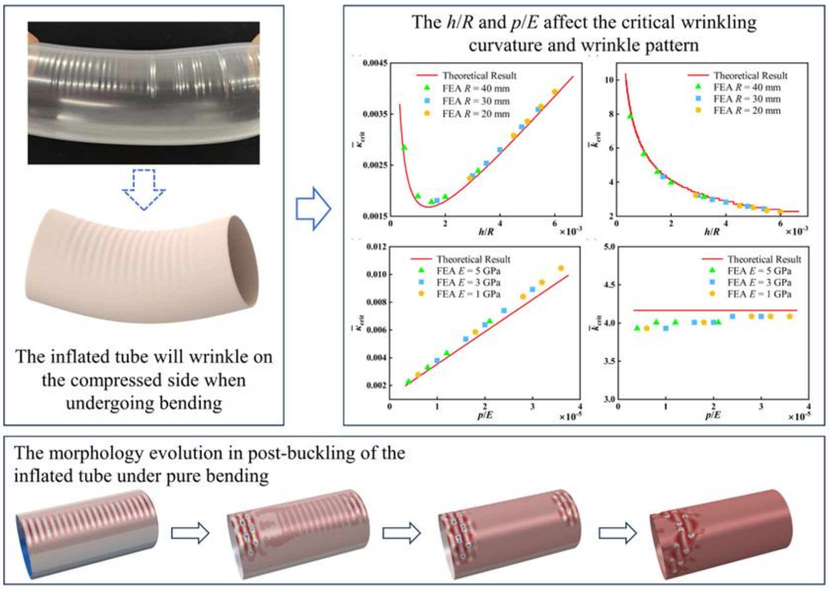

Figure 1. The inflated tube wrinkling behavior under pure bending

Synergizing low dielectric constant with Robust Mechanical and Thermal Properties in Dual-Phase Amorphous Boron Nitride Interconnects

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The relentless scaling of integrated circuits toward the sub-3 nm node has been severely throttled by the dielectric trilemma—the irreconcilable trade-off between ultralow dielectric constants (k), mechanical robustness, and thermal dissipation. Traditional porous dielectrics, while achieving low k, suffer from catastrophic mechanical failure and thermal bottlenecking. Herein, we report a structurally engineered dual-phase amorphous boron nitride (aBN) film that overcomes these fundamental limits. By embedding localized nanocrystalline domains within a disordered atomic network, we decouple electrical polarization from structural integrity. Our aBN achieves an ultralow k ≈ 2.3 with exceptional high-frequency stability, while simultaneously delivering a high Young's modulus (≈ 72.9 GPa) and superior in-plane thermal conductivity, far outperforming conventional porous insulators. Notably, in situ microscopy and atomistic simulations reveal a self-healing mechanism driven by the dynamic reconfiguration of abundant dangling bonds, granting the film unprecedented resilience under cyclic stress and robust interfacial adhesion. These synergistic properties establish dual-phase aBN as a transformative platform for next-generation, high-performance, and reliable electronic interconnects.

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Compositionally Tuned Enhancement of Phase Transformation Compatibility in Pyroelectric Energy-Harvesting Materials

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The growing demand for sustainable energy solutions has intensified interest in harvesting low-grade waste heat, existing as temperature fluctuations in both industrial processes and daily life. Pyroelectric energy conversion, which exploits the temperature-dependent polarization of ferroelectric materials, offers a particularly effective approach for converting heat to electricity directly. First-order phase transformations in ferroelectric materials can significantly enhance the figure of merit (FOM) of energy conversion by inducing an abrupt change in polarization during phase transformation. However, the accompanying symmetry-breaking structural transitions often lead to microstructure incompatibility, which degrades cyclic functional stability and diminishes energy harvesting performance over thermodynamics cycles.

In this work, we proposed a material development strategy to optimize the FOM in pyroelectric energy conversion by tuning the phase transformation compatibility of crystal structure in barium titanate material system with strontium (Sr) doping. As the Sr concentration increases, we observed a shift in phase transformation behaviour from first-order-like to second-order-like, accompanied by concurrent changes in thermal, electrical, and ferroelectric properties. Through crystal structural analysis, we calculated the compatibility conditions for this (Ba,Sr)TiO3 material system and identified the optimal compositions with the lowest thermal hysteresis during phase transformation. Our findings demonstrate that these compatible compositions yield the highest FOM and low leakage current density, thereby enhancing the practical pyroelectric energy conversion performance.

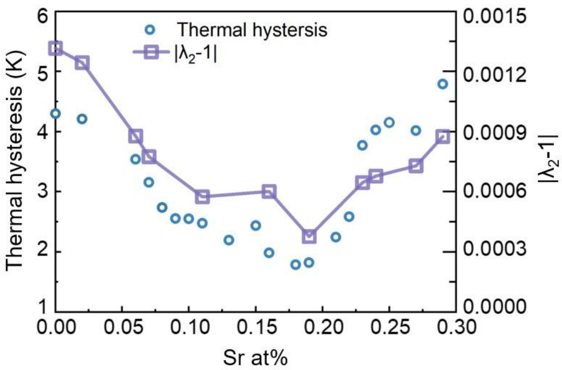

Figure 1. Thermal hysteresis calculated from DSC results with |λ2-1| calculated from lattice parameter characterized with synchrotron XRD, ALS beamline 12.3.2..

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Parallel Session B1

Capillary Effects in Complex Droplet Impact

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Droplet impact and rebound are fundamental interfacial phenomena central to spray combustion, anti-/de-icing, self-cleaning, and energy harvesting. Classical studies show that rebound dynamics are governed by a balance among inertia, surface tension, viscosity, and interfacial dissipation [1,2]. Most existing control strategies rely on surface engineering, such as superhydrophobic coatings and micro/nanotextures [3], but these approaches often lack adaptability and robustness under complex or extreme conditions. This motivates an alternative paradigm: controlling impact dynamics through the intrinsic properties of the droplet. A key challenge is to either suppress rebound for deposition and heat transfer or enhance rebound to minimize contact time for anti-icing. Achieving both objectives within a unified framework remains difficult because conventional single-phase droplets offer limited tunability of internal flow, dissipation, and elasticity.

Here we summarize our recent progress in addressing this challenge by engineering *non-classical droplets* with tailored internal structures, phase compositions, and thermocapillary responses. First, we show that hollow droplets impacting super-repellent surfaces can exhibit strongly suppressed rebound. The internal cavity generates counteractive capillary effects during impact, reorganizing internal flow and reducing take-off momentum, thereby breaking the conventional rebound criterion on superhydrophobic substrates [4]. Second, particle-laden core–shell droplets are demonstrated to undergo ultrafast rebound with contact times far below the inertio-capillary limit. The particulate shell provides transient solid-like elasticity, enabling efficient energy storage and release while suppressing viscous dissipation, leading to solid–liquid hybrid impact dynamics [5]. Third, by tuning the dispersed-phase volume fraction in liquid–liquid compound droplets, we reveal a continuous transition from rebound suppression to enhancement, corresponding to a shift from viscous- to elastic-dominated response [6]. Finally, for high-temperature impacts, thermocapillary-driven Marangoni flows stabilize the interfacial vapor layer, producing a self-lubricated state and enhanced rebound even at elevated temperatures [7]. These results establish droplet-property engineering as a powerful route for effectively controlling impact dynamics and open new opportunities in thermal management, anti-icing, and multiphase transport.

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A Hybrid TENO-NA-CON + THINC Scheme for Simulating Evolving Material Interface Flows within the Quasi-Conservative Framework

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The simulation of multi-phase flows with evolving material interfaces remains a challenging frontier in computational fluid dynamics (CFD) due to complex flow structures and the high susceptibility to non-physical numerical oscillations. Although early studies introduced quasi-conservative frameworks to mitigate velocity and pressure oscillations at interfaces, these methods were largely confined to finite volume frameworks and offered limited suppression efficacy. Subsequently, consistent discretization strategies based on WENO schemes made progress in suppressing global oscillations but struggled to overcome the inherent excessive dissipation of classical WENO formulations, resulting in insufficient resolution at material interfaces. In light of this, the present study aims to overcome these performance bottlenecks by first verifying the applicability of the non-conservative system within a finite difference framework and successfully transplanting the consistency strategy into the low-dissipation, high-precision TENO-NA scheme. Subsequently, a dual-identification mechanism based on a dual-component TENO indicator is designed. This mechanism distinguishes various flow discontinuities and precisely locks onto material interfaces to adaptively activate the THINC scheme for sharp reconstruction. Based on this approach, a novel hybrid scheme named TENO-NA-CON+THINC is proposed. Theoretical and numerical analyses demonstrate that the scheme maintains optimal accuracy in smooth regions. Furthermore, the dual-identification strategy effectively eliminates non-physical oscillations in density, velocity, and pressure while achieving sharp capturing of evolving interfaces, exhibiting superior performance that balances numerical robustness with high-fidelity resolution.

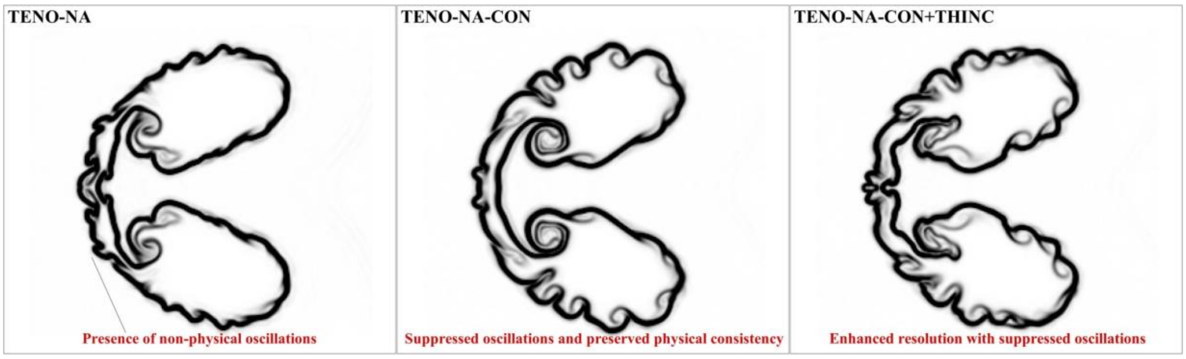

Figure 1. Comparison of density gradient contours for the shock-bubble interaction simulation at t=0.4.

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Numerics and physics of bubble cloud dynamics

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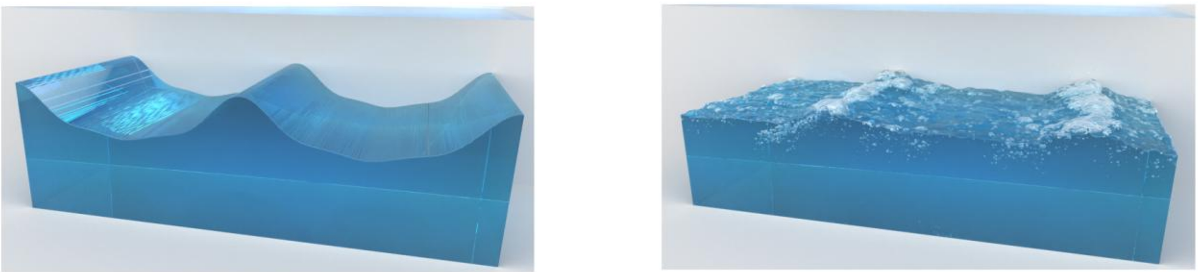
Abstract: numerical simulation of multiphase flows plays a pivotal role in unravelling the complex physics of interface evolution, wave breaking, and bubble dynamics—phenomena critical to ocean engineering and fluid mechanics. Owing to the challenges of resolving turbulent interface deformation, bubble entrainment, and multiscale flow interactions in experimental settings, high-fidelity computational simulations have become indispensable tools for quantitative investigation and mechanism analysis. This work presents a rigorous numerical study of air-water multiphase flow, focusing on the transient evolution of free-surface waves and the subsequent bubble entrainment process during wave breaking. A series of state-of-the-art computational fluid dynamics (CFD) numerical methods are employed, including the Volume-of-Fluid (VOF) and multi-VOF method for sharp interface tracking with the piecewise linear interface characterization (PLIC) reconstruction. Quantitative analysis of the simulation results further elucidates the key physical mechanisms governing energy transfer, interface instability, and bubble entrainment during wave breaking. The findings validate the robustness and accuracy of the proposed numerical framework, establishing it as a reliable tool for simulating challenging multiphase flow problems.



$t = 0$ $t = 4.7$

Figure 1. The wave breaking simulation.

Acknowledgements

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Theoretical modeling of critical sticking velocity in adhesive particle collisions based on the Johnson–Kendall–Roberts theory

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This study proposes a critical sticking velocity model for adhesive particle collisions to predict the threshold between adhesion and separation after impact based on Johnson–Kendall–Roberts (JKR) theory. The model systematically accounts for multiple energy dissipation mechanisms associated with adhesive interactions, contact forces, and gas flow effects. The collision process is divided into four stages: approach, compression, restitution, and separation. Energy dissipation due to adhesive interactions is represented by an adhesive damping term, while contact-induced energy losses are described using a viscous damping formulation. In addition, squeeze film damping under ambient pressure conditions is incorporated to capture energy dissipation caused by air resistance. On this basis, the energy conversion and dissipation mechanisms at each collision stage are quantitatively analyzed. By enforcing energy conservation, a dynamic critical sticking velocity model is derived as a function of the coefficient of restitution (CoR). Comparisons with existing critical sticking velocity models demonstrate that the proposed formulation provides improved predictive accuracy and broader applicability. The results indicate that the critical sticking velocity is jointly governed by adhesive and contact forces, with particle size playing a dominant role. Specifically, as particle size increases, the critical sticking velocity decreases rapidly at first and then gradually approaches an asymptotic value. Finally, extensive experimental data are used to validate the accuracy and reliability of the proposed model.

Keywords: adhesive particles; critical sticking velocity; adhesive damping; viscous damping; Johnson-Kendall-Roberts theory

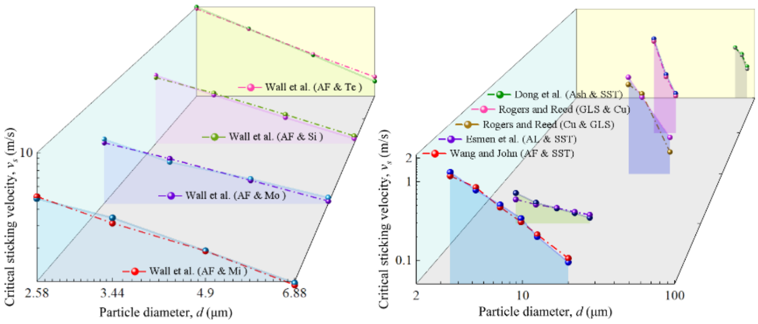

Figure.1 Comparison of the proposed model with the experimental data reported by five other researchers.

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The composite mean velocity profile in adverse pressure gradient and turbulence modeling

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This paper aims to improve the prediction accuracy of the SST turbulence model for the mean velocity profile in flows with adverse pressure gradients. In flows with APGs, the mean velocity profile shows characteristics different from those in zero pressure gradients. A square-root law appears above the log law region. The traditional SST model cannot accurately reproduce this key feature. To solve this problem, this paper first establishes a composite mean velocity profile under APGs by combining the symbolic regression method. A systematic theoretical analysis of the SST model is conducted and the analytical solution compatible with the mean velocity profile under is then derived. Based on this solution, the correction coefficient for the dissipation term of the ω equation is determined. To verify the performance of the modified model, several typical test cases are selected for numerical simulation. The results show that compared with the traditional SST model, the modified model provides more accurate predictions for key parameters such as the mean velocity profile and wall friction coefficient in different adverse pressure gradient flow cases. It effectively improves the applicability and prediction accuracy of the model in APG flows.

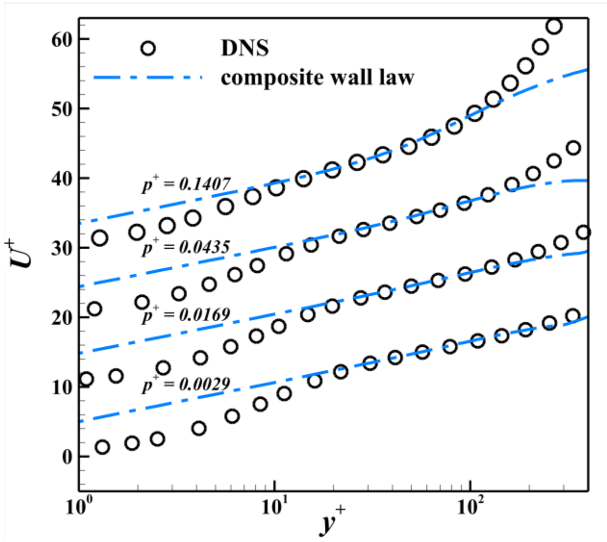

Figure 1. A comparation between the composite wall law and DNS data.

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Improving Condensation Heat Transfer Using Micropillar Surface Topography and Hybrid Wettability

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Driven by the urgent demand for efficient heat dissipation in high-power-density electronic devices and aerospace thermal control systems, this study numerically investigates the condensation heat transfer on several representative micro-structured surfaces. The effects of three micropillar surface topographies (i.e., triangular, quadrangular, and hexagonal) on droplet dynamics and thermal performance are systematically analysed under different wettability conditions (i.e., hydrophilic, superhydrophobic, and hybrid). The results reveal that the geometric features of micropillars play a pivotal role in regulating the trade-off between the nucleation energy barrier and contact line pinning effects. Specifically, for surfaces with hybrid wettability (i.e., hydrophilic pillar tops with superhydrophobic substrates), vertical migration driven by the wettability gradient is observed. This mechanism promotes the upward transport and anchoring of droplets onto the pillar tops, effectively preventing surface flooding while sustaining an efficient suspended condensation mode. Overall, the hybrid wettability design enhances the peak heat flux by 25.6% ~ 49.9%. Among the three arrays, the triangular micropillar array achieves a remarkable peak heat flux of 1283 kW/m² and the highest liquid volume growth rate. This study elucidates the synergistic mechanism between micropillar surface topography and wettability distribution, providing a guidance for the optimal design of micro-structured condensation surfaces.

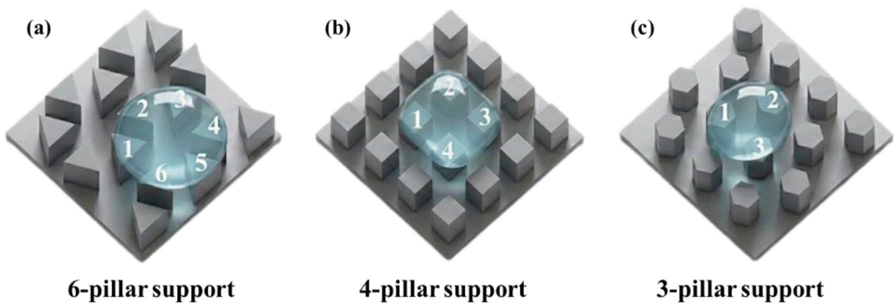

Figure 1. Schematic illustration of suspended droplets on hybrid wettability surfaces with (a) triangular, (b) quadrangular, and (c) hexagonal pillars.

Acknowledgements

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Parallel Session B2

Deformation and Breakup of Water Droplet in Shear Airflow

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The dynamic motion of supercooled large water droplets (SLDs) in airflow involving deformation, breakup and splash, affects local collection coefficient, resulting in an increase of complexity of aircraft icing. To deepen the acknowledge of aircraft icing mechanism in SLDs, parametric research on the influence of motion deformation of a single water droplet in the shear flow was carried out. In this study, a horizontal wind tunnel was used to create the background shear airflow, and a high-speed camera recorded the deformation and breakup process of a water droplet under actions of gravity and airflow. The key geometric parameters, including cross-stream diameter, streamwise diameter and geometric center were extracted. The deformation modes of the droplet are categorized into five regimes: stabilization, vibration, transition, bag breakup, and bag-stamen breakup. A dimensionless deformation factor *L* is defined to describe the droplet deformation, which increases with airflow speed. Two models are proposed to predict the maximum deformation factor based on the initial Weber number and transient Weber number, respectively. Applying the scale expression to describe the effects of initial droplet volume and shear aerodynamic force, a normalized acceleration model of water droplet is established. The breakup critical conditions are determined by both the initial Weber number and deformation factor. When deformation factor L exceeds 3.5 or initial Weber number exceeds 10.3, the droplet enters breakup mode. Furthermore, as initial Weber number exceeds the critical value of 17.5, the deformation droplet occurs bag-stamen breakup.

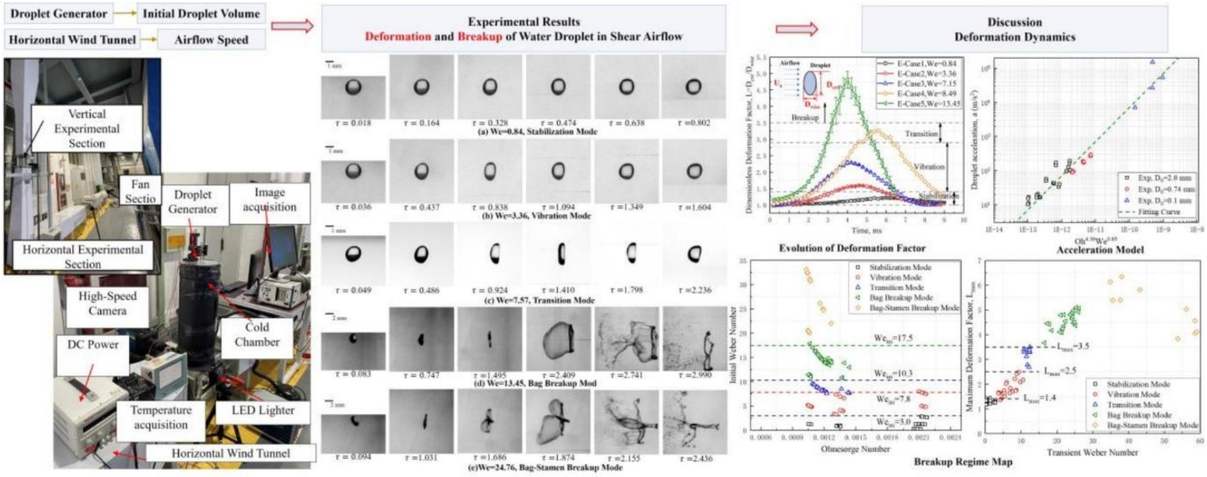

Figure 1. Experimenal setup, visualization of the droplet deformation and breakup and dynamics models.

Acknowledgements

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An Improved Baldwin-Lomax Model for Complex Hypersonic Flows

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Accurate prediction of hypersonic turbulent boundary layers is crucial for the design of hypersonic vehicles. Conventional turbulence models, like the Baldwin–Lomax (BL) model, were developed for incompressible flows and struggle under hypersonic cold-wall conditions. Recently, Chen et al. (2024) proposed an improved BL model by incorporating velocity transformations and the temperature–velocity (T–V) relation, achieving notable improvements for zero-pressure-gradient flat-plate flows. Building on their work, the present study introduces further enhancements: limiting the search range for the maximum vorticity function value, restricting the T–V relation to the logarithmic layer, and adopting a more robust boundary layer edge determination method. The final improved BL model is validated against direct numerical simulation (DNS) results and experimental data for two- and three-dimensional hypersonic cases involving pressure gradients, cold walls, and shock/boundary-layer interactions. Figure 1 presents the simulation results for a sharp cone/flare configuration at Mach 6 (Sun et al., 2025). It shows that the improved model generally yields better velocity and temperature predictions compared to the baseline BL model and other commonly used models, indicating its potential for practical hypersonic flow simulations.

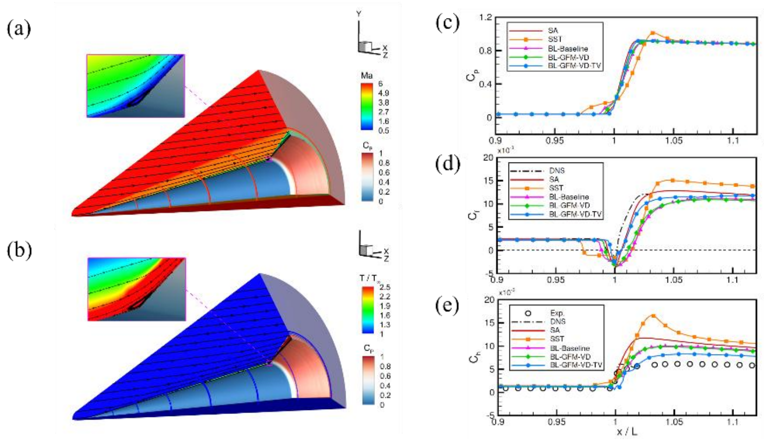

Figure 1. Simulation results for the hypersonic cone/flare configuration. (a) and (b) present the spatial flow field contours for Mach number and temperature, respectively, along with surface pressure coefficient distributions. (c), (d) and (e) compare the streamwise distributions of the wall pressure, skin friction, and heat transfer coefficients predicted by various turbulence models.

Acknowledgements

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Dynamic modeling of microrobot–vessel collision within a 3D flexible vascular system for thrombus removal

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This study proposes a flexible system dynamics model for the thrombus removal process in the human vascular system, aiming to overcome the limitations of conventional rigid-boundary models in accurately describing the flexible deformation of biological tissues and the energy dissipation characteristics during collision events. Considering the significant geometric nonlinearity and thin-walled structural features of blood vessels, a dynamic model of the thin-walled vascular structure is established using shell elements based on the Absolute Nodal Coordinate Formulation (ANCF). The Enhanced Mid-surface Method (EMM) is employed to modify the strain field, effectively eliminating Poisson locking and thickness locking issues commonly encountered in traditional continuum models under large deformation conditions. On this basis, a stepwise configuration evolution strategy consisting of 'planar discretization–geometric rolling–topological suturing' is proposed to construct a geometrically continuous three-dimensional stress-free flexible vascular model. Furthermore, to describe the collision behavior between microrobot and the vessel wall within a three-dimensional flexible vascular environment, a nonlinear viscoelastic contact force model is adopted to compute the contact forces. Subsequently, proportional damping is introduced to account for the influence of blood flow on robot motion. A multi-field coupled flexible system dynamics model incorporating rigid–flexible coupling, fluid effects, and collision interactions is thus established. Finally, the validity and accuracy of the proposed model are verified through Finite Element Method (FEM) and experimental testing. Simulation results demonstrate that the model accurately characterizes the nonlinear elastic deformation of the vascular wall and effectively captures the dynamic response of microrobot within a three-dimensional flexible vascular system. The present study provides a theoretical and mechanical foundation for the clinical application of microrobot in thrombus removal.

Keywords: Thrombus removal; three-dimensional flexible vascular; contact and impact; microrobot; multi-field coupled flexible system

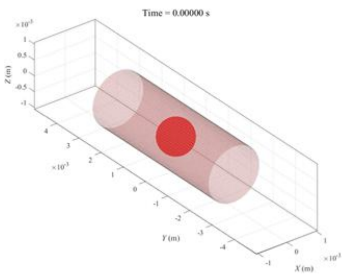

Figure 1. Initial state of particles in a flexible channel.

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An Integrated Experimental and Computational Platform for Assessing Microclimate of Sports Footwear

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This study presents a new platform integrating wind-tunnel experiments and computational fluid dynamics (CFD) simulations for the comprehensive evaluation of microclimate and aerodynamic performance of sports footwear. A custom-developed foot manikin[1] with integrated heating and humidity generation units simulates thermal and sweating processes, while real-time sensors monitor temperature and humidity. The CFD framework, validated against experimental data, incorporates 3D-scanned footwear geometry, porous media for mesh fabric, species transport for sweat diffusion, and metabolic heat[2] and sweat[3] generation. With this platform, the microclimate performance of different footwear designs was compared: the effects of breathable mesh at different locations with different permeability on thermal comfort were analyzed, aiming to determine the best layout of the footwear (Figure1 (b)). Meanwhile, the application of phase change materials (PCMs) in regulating the microclimate has also been explored (Figure1 (c)). This ongoing work provides valuable insights for designing thermally comfortable sports footwear.

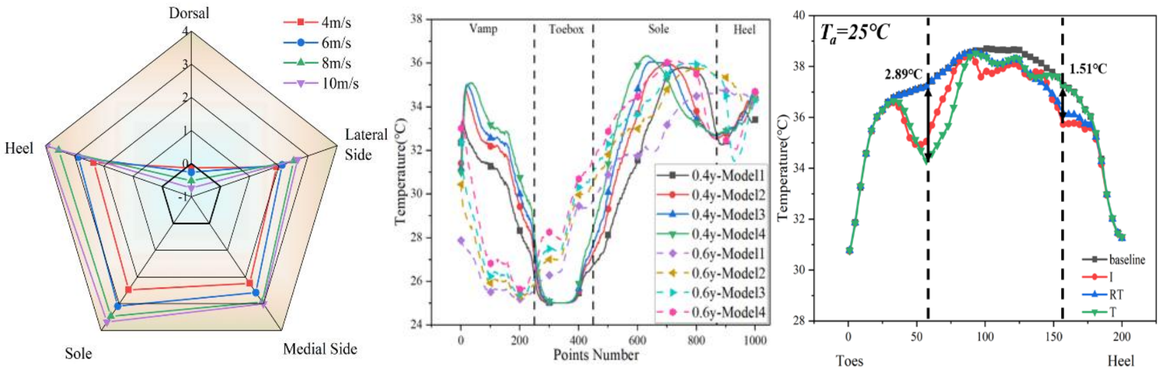

Figure 1 (a) Thermal comfort distribution based on the CFD results; (b) Temperature distribution corresponding to different mesh fabric positions; (c) Temperature control performance for different PCMs layouts.

Acknowledgements
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Curvature correction effects on airfoil separated flows at high angles of attack

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Accurately capturing rotational and streamline curvature effects remains a persistent challenge in turbulence modeling. This work explores the influence of a rotation-curvature correction within the SST-DDES framework on separated flows at high angles of attack over the NACA4412 airfoil, and clarifies the underlying physical mechanisms. A novel mechanistic insight is uncovered: the curvature correction, through the sensitivity function $Fr1$, suppresses vortex stretching—especially in the streamwise and spanwise orientations—thereby reducing enstrophy generation. This suppression leads to attenuated vorticity development, diminished turbulent kinetic energy, and a restrained dissipation rate. As a result, non-physical dissipation within vortex cores is markedly alleviated, yielding more coherent vortical structures and improved fidelity in capturing unsteady flow evolution. The causal pathway identified—spanning stretching suppression, enstrophy reduction, and the rebalancing of production and dissipation—provides a deeper understanding of curvature-influenced turbulent flows.

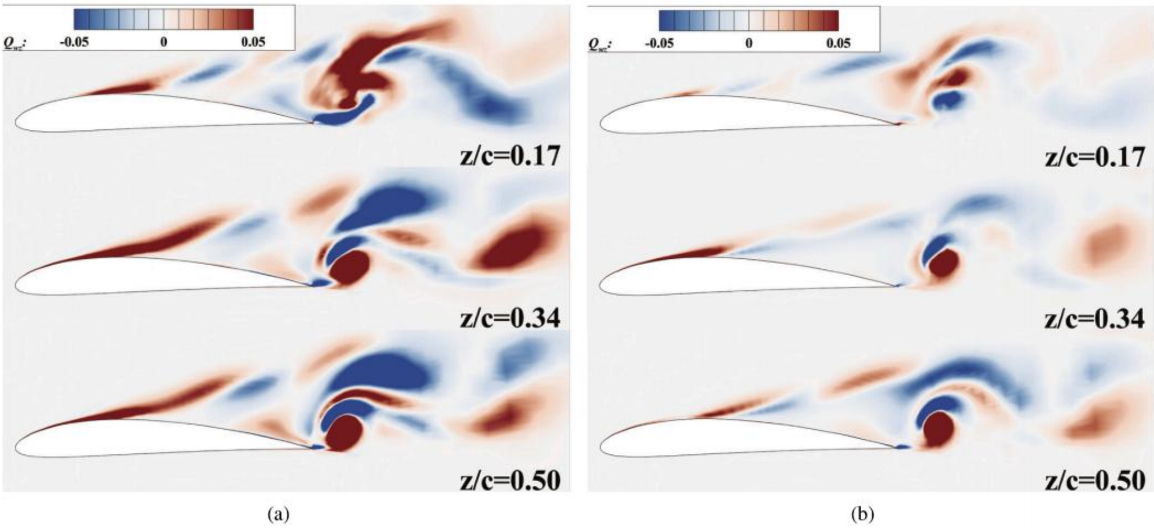

Figure 1. The spanwise components of the stretching term in the vortex transport equation: (a) SST-DDES model and (b) SST-DDES-RC model.

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Parallel Session C1

Study on the Interface ITZ Thickness Induced by Concrete Hydration Heat Based on Temperature Stress Elasto-Plastic Solution

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The Interfacial transition zone ITZ between aggregate and mortar is the weak surface in concrete. Research on the thickness of ITZ is of great significance to the safety of concrete structures. However, up to now, there have been few research results on the ITZ thickness induced by hydration heat, especially no analytical solution for the ITZ thickness of concrete has been found. In this study, the elasto-plastic solution of the temperature stress of spherically symmetric double-layer structures and the analytical expressions of ITZ thickness caused by thermal expansion are derived. Based on this, the quantitative relationship between ITZ thickness and various factors influencing thermal expansion was revealed. It was found that the elastic modulus difference and temperature difference between mortar and aggregates, as well as the internal friction angle of mortar, are the primary controlling factors affecting the thickness of thermal expansion ITZ. The results of this paper fill the theoretical research on the influence of hydration heat on the ITZ thickness of concrete and provides a scientific basis for improving the mechanical properties of the interface between aggregates and mortar.

Keywords: Spherical symmetrical structure; Temperature stress elasto-plastic solution; Heat of hydration of Concrete; ITZ thickness; Influencing factors of ITZ thickness due to thermal expansion

Optical Measurement of Concrete Fracture Interfaces Using Fringe Projection: Methodology, Fracture Morphology, and Durability Mechanisms in Sustainable Concrete

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Concrete fracture interfaces record essential information on crack propagation and energy dissipation, and their three-dimensional (3D) characterization is critical for understanding fracture behavior and durability of sustainable concrete materials. This study develops a unified framework for 3D characterization of concrete fracture interfaces using fringe projection technology. The non-contact optical method enables efficient point-by-point reconstruction of irregular fracture surfaces with a height measurement error below 0.1 mm. Fracture morphology is quantitatively described using surface roughness and fractal dimension, which characterize global geometric irregularity and scale-dependent complexity, respectively, and establish a direct link between fracture geometry and mechanical response. Systematic investigations on normal concrete, RAC, and recycled aggregate seawater–sea sand concrete (RASSC) reveal that decreasing the water-to-binder ratio reduces surface roughness and fractal dimension due to enhanced matrix strength and a transition of crack paths from ITZ-controlled propagation to aggregate fracture. In RASSC, prolonged seawater immersion induces a failure mode shift from ITZ- to recycled aggregate-dominated fracture. Incorporating the measured fracture surface area into fracture energy analysis further improves the assessment of energy dissipation. Overall, fringe projection provides an effective tool for linking fracture morphology, mechanics, and durability of sustainable concrete.

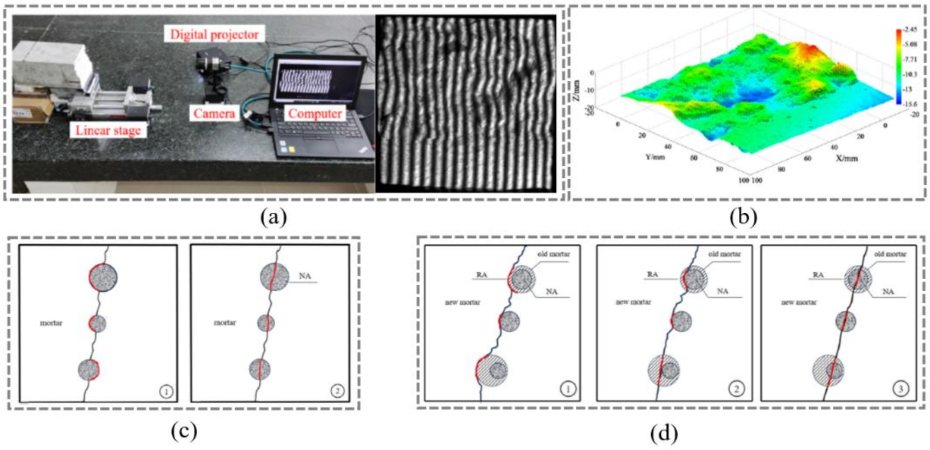

Figure 1. (a) Fringe projection experimental setup and representative fringe pattern; (b) three-dimensional reconstruction of a concrete fracture surface; schematic comparison of fracture paths in (c)normal concrete (NC) and (d)recycled aggregate concrete (RAC), highlighting the role of interfacial transition zones.

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Analysis of Forces on Tunnel Linings and the Consequent Uplift Problem

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During shield tunnelling, the synchronous grouting material filled behind the newly assembled segments is essential for controlling ground settlement. However, the fresh grouting material in its fluid state can exert significant buoyant forces on the lightweight segments before it hardens. Investigating this mechanism is crucial for predicting and mitigating segment uplift, which directly impacts tunnel construction quality, waterproofing performance, and long-term structural safety. This paper analyses the equilibrium of forces acting on a tunnel lining segment, specifically the buoyant force and the combined weight of the lining and enclosed air, as illustrated in Figure 1. The buoyant force is determined using Archimedes' principle, while the self-weight of the lining is calculated via Newton's law. Findings from the Macau East Line tunnelling project indicate that the buoyant force acting on the tunnel lining is 4.75 times greater than the combined weight of the lining and air, resulting in lining segment uplift. Uplift can only occur when the grout is displaced downward by the rising segments. The yield stress of the grout acts to resist this movement. However, the theoretical minimum yield stress required to prevent uplift was found to be more than twice the value achieved by the grout used in the project. This discrepancy helps explain the observed uplift in terms of grout material behaviour. Reducing grout density or increasing its yield stress are recommended solutions.

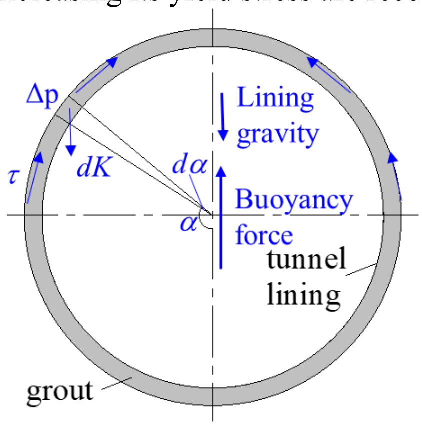

Figure 1. Schematic illustration of the forces acting on the tunnel lining and surrounding grout.

Acknowledgements

The research was funded by Science and Technology Development Fund of Macau SAR (File/Project nos. 0082/2024/RIB2, and 0014/2024/AFJ) and the University of Macau Development Foundation (File/Project nos. MYRG-CRG2025-00037-IOTSC).

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Modeling and Analysis of Frequency-Varying Equivalent Impedance in Vehicle Inertial Suspension Systems

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This work proposes a Frequency-Dependent Equivalent Impedance (FDEI) method (Figure 1a) to analyze the dynamic behavior of mechanical networks and enhance vehicle inertial suspension performance through structural optimization. As illustrated in Figure 1b, we investigate the equivalent impedance of two-element and three-element mechanical networks, leveraging these characteristics for both inerter design and suspension applications. The study elucidates the relationships between equivalent stiffness, damping, and inertance with their associated parameters (e.g., Figure 1c). Furthermore, a suspension model is analyzed to explore the fundamental link between equivalent impedance and suspension performance. Additionally, a nonlinear dynamic model of a fluid inerter is established and analyzed using the FDEI method. A fluid inerter prototype was fabricated and tested; its parameters were identified, and the output force was verified through bench tests. Experimental results indicate that the impact of nonlinear factors varies across different frequency ranges. An inertial suspension model incorporating this nonlinear fluid inerter was also developed. Comparative analyses of traditional suspensions, inertial suspensions with an ideal inerter, and those with a nonlinear fluid inerter reveal that the proposed structure significantly improves vibration isolation quality, although nonlinear factors somewhat compromise performance. Ultimately, the FDEI method offers a robust framework for optimizing vehicle inertial suspensions and provides design guidelines for inerter-based vibration isolators.

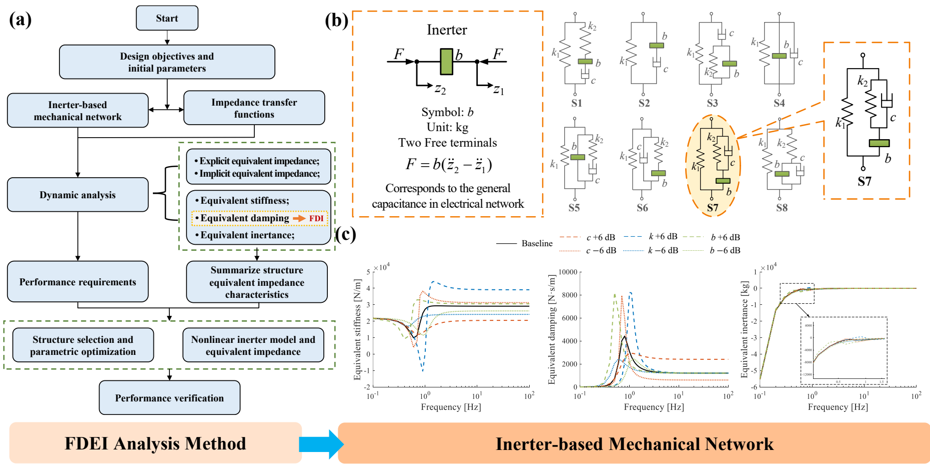

Figure 1. Frequency-dependent equivalent impedance analysis for optimizing vehicle inertial suspensions.

Acknowledgements

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The interaction mechanism of dam-reservoir-foundation during impoundment: Case study of the Xiluodu Project, China

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Clarifying dam-reservoir-foundation interactions during reservoir impoundment is fundamental to dam safety assessment. However, the internal dynamics and spatiotemporal evolution of these interactions remain elusive due to multifactorial complexities. To investigate the interaction mechanism in the dam-reservoir-foundation system during impoundment, a feedback-driven dynamic double-displacement boundary method is developed based on observed large-scale irreversible translational deformation phenomena in reservoir banks, implemented within a nonlinear finite element framework. Subsequently, real-time dynamic numerical simulations of the Xiluodu Project incorporating actual impoundment schedules and dam construction sequences are conducted. The results show that the simulated and monitored deformation behaviors of the dam-reservoir-foundation system exhibit good agreement. Valley contraction is primarily driven by large-scale mountain translational deformation, while fluctuations in reservoir water level induced characteristic oscillations in the near-dam valley deformation curves. Reservoir water pressure causes foundation settlement, whereas sustained valley contraction induces foundation uplift. Dam crest displacement shows clear water-level dependency, and valley contraction caused abutment compression, which drives upstream-directed displacement of the arch dam. These two effects exhibit linear superposition behavior. This study provides critical insights for the safety assessment of high arch dams.

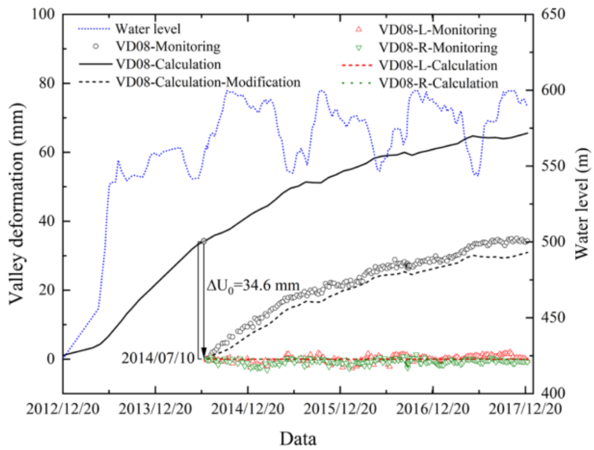

Figure 1. Comparison between monitored and simulated values of valley contraction

Acknowledgements
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A Computational Strategy for Enhanced Nonlinear Structural Stability Analysis in Abaqus

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Buckling and post-buckling analysis is important in both structural safety assessment and the design of functional buckling-enabled systems. This work presents a computational strategy for nonlinear stability analysis in *Abaqus*, combining critical-point detection with a probing-based branch-switching method. By applying small probing forces in the direction of the critical eigenvector, the method enables the automatic tracing of secondary equilibrium branches without introducing artificial imperfections.
The approach is demonstrated using two representative examples: a circular ring under external pressure, and a shallow shell roof under concentrated loading. The results show that the method can accurately detect bifurcation points, capture post-buckling paths, and recover complex equilibrium behaviour in practical finite element models.
The proposed framework provides a simple and effective tool for bifurcation analysis in commercial finite element software, with potential applications in structural engineering, shell mechanics, and buckling-guided design.

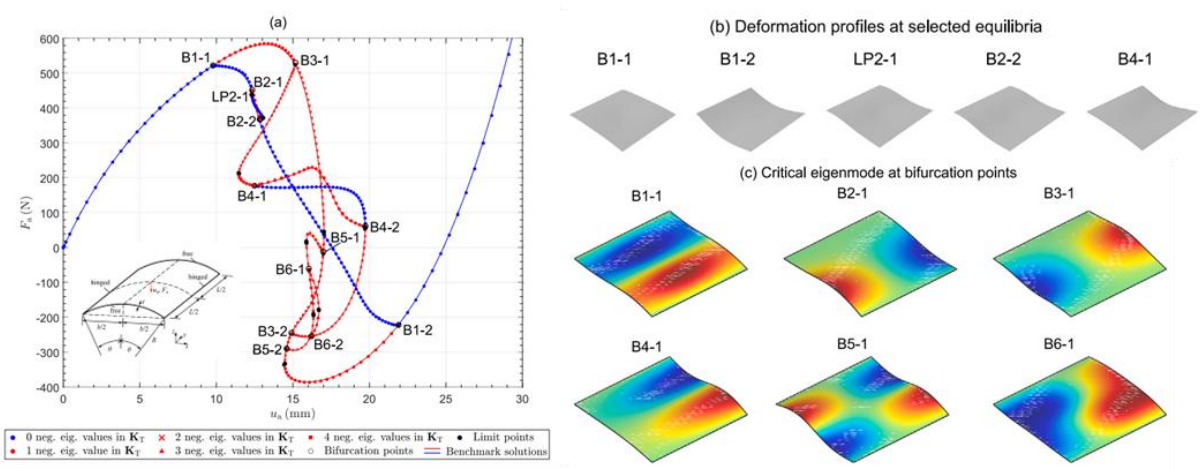

Figure 1. Equilibrium paths of the shallow shell roof under concentrated loading, showing the nonlinear response and post-buckling behaviour captured by the proposed method.

Acknowledgements
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Parallel Session C2

An experimental study of cyclic strength and stiffness degradation of sand with clayey fines

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Seabeds composed of sand with clayey fines represent a major risk for the installation and operation of marine structures, because they are highly susceptible to localised liquefaction under marine cyclic loading, which can lead to catastrophic failures such as pile running. In this study, artificially prepared sand with clayey fines was tested through a series of dynamic simple shear tests to investigate its failure mechanisms and the evolution of the failure envelope under typical marine cyclic loads. Stiffness degradation during cyclic shearing was evaluated through bender element tests. The effects of clay content (CC) and consolidation pressure (CP) on the cyclic response of sand with clayey fines were analyzed. The results reveal that: (1) under τ_{cy} alone, the failure mode evolves from cyclic mobility to flow failure as τ_{cy} increases, whereas under the combined action of τ_a and τ_{cy}, deformation aligns with the direction of τ_a and the failure mode shifts from plastic strain accumulation to limited flow followed by strain accumulation as τ_a increases; (2) with increasing CC and CP, the failure envelope expands while its failure behaviour becomes more brittle, but the S_u-normalised envelope contracts at a given number of cycles to failure, indicating that CC and CP enhance monotonic strength much more than cyclic strength; (3) with increasing CC and CP, the shear modulus after consolidation increases, accompanied by greater stiffness degradation during both monotonic and cyclic shear, with CP exerting a more pronounced effect on the stiffness of sand with clayey fines, whereas CC must exceed a threshold to be effective.

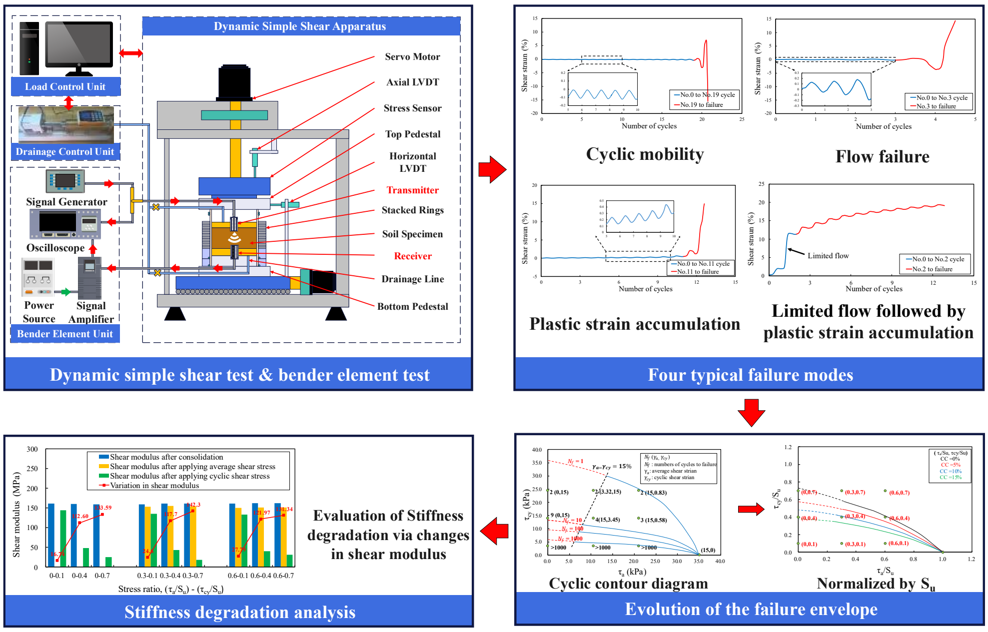

Figure 1. Representative results

Evolution of Unloading–Reloading Moduli in Sand: New Findings and Interpretations

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Unloading–reloading characteristics of soils have long been regarded as approximately elastic recovery processes, yet their sensitivity to anisotropic stress states has rarely been systematically investigated. This study combines advanced consolidated-drained triaxial tests with bender-element measurements to examine unloading–reloading behaviour in sand. It is found that while axial and deviatoric strains recover partially during unloading, both Young's modulus E_{ur} and shear modulus G_{ur} exhibit a clear two-stage evolution: initial stabilisation at low stress ratios, followed by sharp degradation near failure. The unloading–reloading Poisson's ratio ν_{ur} also deviates from the conventional constant assumption, increasing monotonically with a damage parameter, defined as $S = \eta^{us}/M_f$, and even exceeding the elastic limit of 0.5. A strong correlation is found between the small-strain shear modulus G_0 and G_{ur}, suggesting that macroscopic modulus degradation is associated with the structural deterioration of sand specimens. These findings reveal a strong dependence of unloading response on anisotropic stress states and provide new experimental evidence and insights for developing constitutive models capable of reproducing the complex mechanics of sand behaviour.

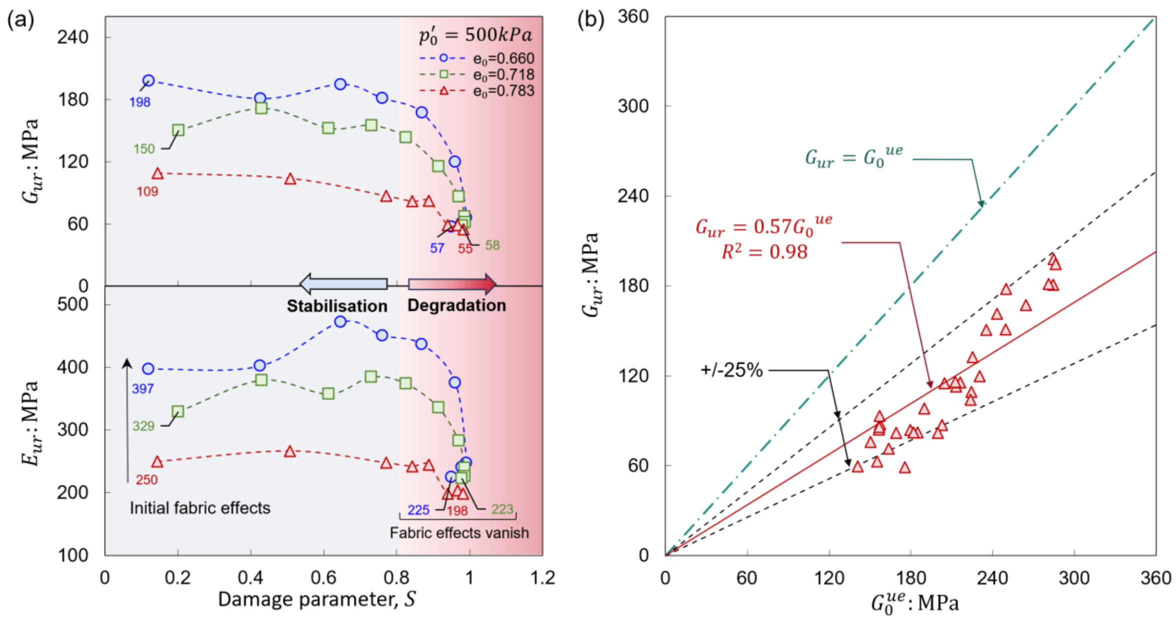

Figure 1. (a) Evolution of G_{ur} and E_{ur} with damage parameter S; (c) Correlation between G_0 and G_{ur}

Acknowledgements
This work is supported by Research Grants Council of Hong Kong under grant number N-HKU723/23.

Rainfall Infiltration Boundary for Unsaturated Soil Slope by Single-Point Two-Phase Material Point Method

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Accurate implementation of rainfall infiltration boundaries is essential for simulating rainfall induced landslide or slope failure mechanisms using the Material Point Method (MPM). Within a single-point, two-phase *u-U* framework, where pore water pressure is not a primary unknown variable and the liquid phase lacks direct Lagrangian tracking, defining infiltration and seepage boundaries presents significant numerical challenges. Investigations reveal that the liquid phase exists in an Eulerian form on the background grid, maintaining a convective relationship with the Lagrangian solid particles. As matric suction (negative pore pressure) exists in the unsaturated soil, artificial water flow occurs due to pore pressure gradient at the boundary of the soil and outside domain. Consequently, it is essential to enforce a velocity-modification scheme at the grid level to regulate the infiltration rate, ensuring it is consistent with the prescribed rainfall intensity, and preventing unrealistic infiltration induced by numerical suction.

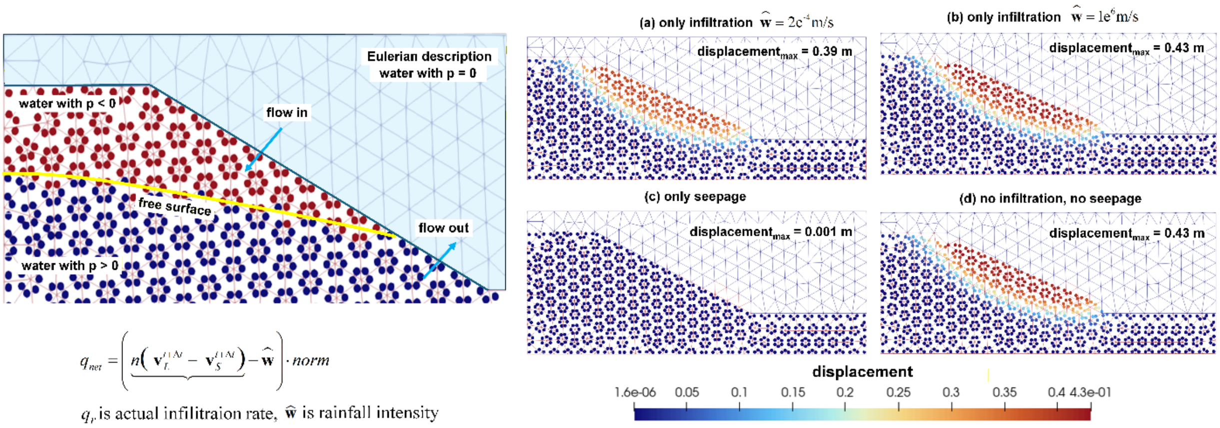

Figure 1. Infiltration/seepage boundary in a single-point two-phase MPM.

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Soil surface erosion simulation using material point method

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Existing continuum-based soil surface erosion modeling has primarily focused on one-phase Eulerian methods, while the use of Lagrangian particle methods, particularly the Material Point Method (MPM), remains limited. Although two-phase MPM formulations for soil-water coupling have been developed, they typically employ conventional elastoplastic soil models that fail to capture the complex soil behavior involving transitions from a static bed to bed-load and suspended-load states. Furthermore, rigorous experimental validation and detailed comparative assessments of MPM for soil surface erosion remain scarce and underexplored. To address these gaps, this study applies the explicit two-phase two-point MPM algorithm to model the soil surface erosion. By employing dual sets of Lagrangian material points on a shared Eulerian grid, the approach effectively resolves soil-fluid interactions during erosion. An effective inflow/outflow boundary algorithm is proposed, enabling the addition and removal of water particles at the boundaries to achieve an efficient fluid boundary. Furthermore, a unified state-dependent constitutive framework for soil-solid is proposed, incorporating an elastoplasticity-μ(I) solid-to-fluid transition constitutive relation and an equation of state. The former captures the nonlinear solid-to-fluid transition behavior of bed-load particles, while the latter describes suspended-load particles. The proposed MPM model is validated against a series of benchmark problems, including dam break, water injection, wall-jet erosion, overtopping erosion, and tsunami overflow erosion scenarios. Comparative analysis demonstrates that the proposed MPM-based surface erosion model accurately captures the soil-fluid interface, bed-load, and suspended-load particle evolution in surface erosion without empirical erosion criteria.

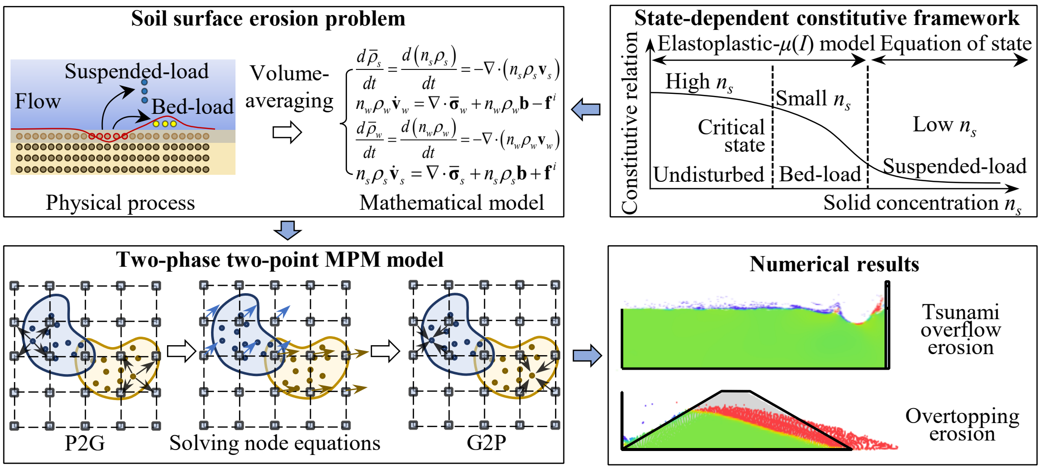

Figure 1. Illustration of the MPM-based soil surface erosion model.

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Achromatic Acoustic Meta-Lens for High-Capacity Underwater Communication Through Acoustic Barriers

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High-capacity and long-distance acoustic signal transmission is vital for wireless underwater communications. However, the presence of acoustic barriers hinders the transfer of acoustic information [1]. In this study, we design an acoustic meta-lens to facilitate high-capacity communication through acoustic barriers with enhanced efficiency, leveraging achromatic ultrasound focusing. The meta-lens is developed by thoroughly considering and utilizing the multi-physical interactions between the meta-structure and the surrounding water media, which substantially amplifies the vibrations of the acoustic barriers and thereby create an effective channel for acoustic signals to traverse. Additionally, the developed meta-lens is capable of transmitting multi-frequency ultrasonic waves while simultaneously focusing sound power at the same position, achieving high-capacity underwater communication characterized by improved signal-to-noise ratio and channel isolation, as conceptually depicted in Fig. 1. By overcoming the narrow bandwidth and dispersive limitations of traditional acoustic metamaterials, this advanced transmission enhancement technology presents a novel approach for developing efficient underwater communication devices in complex environments, with significant potential for applications in marine engineering, acoustic sensing and detection.

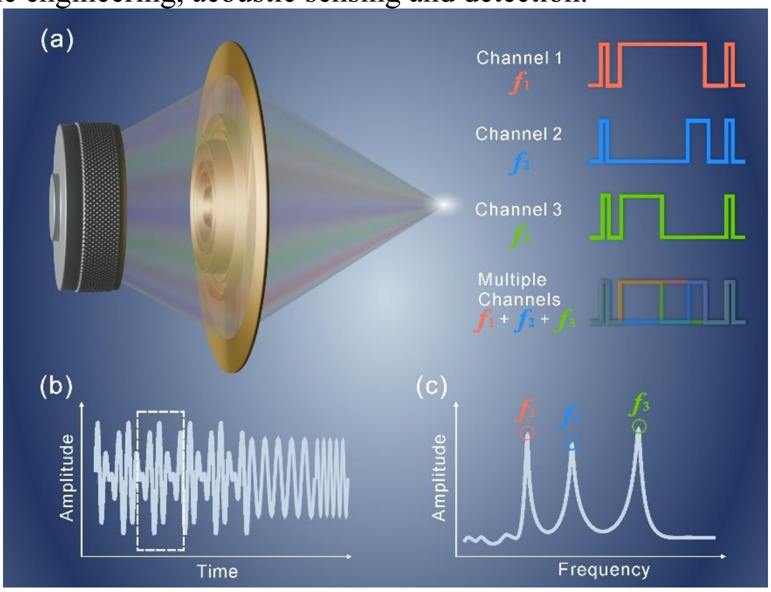

Figure 1. Illustration of high-capacity underwater data transmission.

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Parallel Session D1

Three-dimensional coherent structures for turbulent flow estimation in urban convective boundary layer using generative adversarial networks

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Urban building arrays generate rooftop shear layers, wakes, and three dimensional coherent motions that govern momentum and heat transport within the roughness sublayer (RSL) and the overlying flow, thereby shaping urban ventilation and pollutant dispersion. This study uses conditional generative adversarial network with a single roof level plane as the conditioning input to directly reconstruct three dimensional wind and thermal fields over idealized urban morphology from neutral to free convection. The results show that reconstruction skill is closely tied to how strongly coherent structures imprint on the roof level plane, and the streamwise velocity component is generally reconstructed most accurately. The model preserves the spatial distribution and intensity of dominant coherent structures at multiple heights and directly recovers flux structures primarily associated with sweeps and ejections. Under a unified cross stability model, the reconstructions reproduce key coupled velocity temperature features while maintaining the joint statistical form of momentum and heat fluxes and the location of their high probability cores. Structure matching further indicates that ejection dominated momentum flux events are recovered more faithfully than sweep events, whereas for heat flux the aloft downdraft structures become more coherent with increasing instability and exhibit higher reconstruction consistency.

Acknowledgements

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A multi-scale topology optimization framework for high-performance TPMS based piezoelectric metamaterials via deep learning surrogate models

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Advances in additive manufacturing of piezoelectric materials have highlighted the topology optimization of triply periodic minimal surface (TPMS)-based metamaterials as a critical frontier for next-generation sensors and actuators. However, topology optimization design of these materials has largely been restricted to single-scale or 2D models due to the prohibitive computational cost arising from complex cross-scale electromechanical coupling. To address this issue, we present a multi-scale topology optimization framework centered on a data-efficient deep learning surrogate model for TPMS-based piezoelectric metamaterials. This surrogate model rapidly predicts the effective properties of TPMS microstructures, enabling efficient multi-scale optimization for practical applications. Our framework allows for the simultaneous optimization of lattice density and piezoelectric polarization directions across arbitrary 3D macroscopic geometries. Numerical results demonstrate that this concurrent optimization strategy yields a 156.1% enhancement in output displacement for the TPMS-based actuator compared to the conventional one with uniform density and symmetrical polarization. This multi-scale topology optimization framework establishes a feasible and efficient pathway to unlock the full design potential of high performance, architected piezoelectric metamaterials and devices.

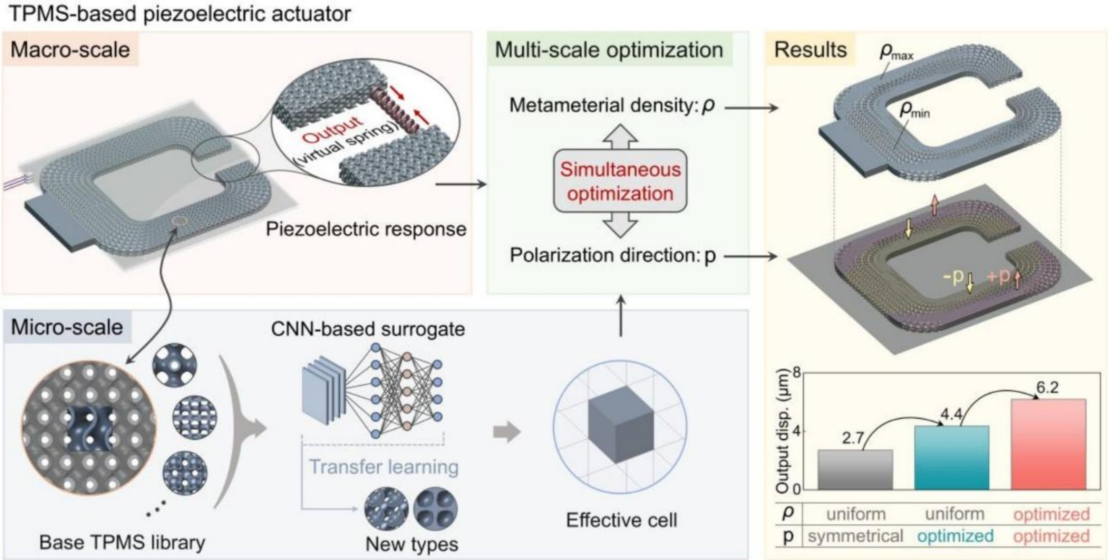

Figure 1. Multi-scale optimization workflow and resulting performance of TPMS-based piezoelectric actuators

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Efficient Optimization of High-dimensional Engineering Problems

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To address the high computational cost and resource demands of high-dimensional engineering optimization, this study introduces a newly developed DANTE algorithm (Wei et al.) into aerodynamic optimization problems. Leveraging its exceptional global-optimum searching capability, DANTE is employed to improve the aerodynamic performance of the RAE 2822 airfoil with 20 design variables and the M6 wing with 36 design variables. To further reduce simulation cost and fully utilize the existing data, a Kriging model, known for its strong nonlinear fitting and predicting accuracy, is established for predicting aerodynamic performance of new shapes, as shown in Figure 1. Figure 2 demonstrates that DANTE can decrease over 70% of the sampling number for identifying the global optimum compared with Bayesian optimization, significantly improving the optimization efficiency. Figure 3 further illustrates that DANTE can quickly skip local optimums and maintain exploration behavior around the global optimum. These substantial performance gains highlight the strong potential of this approach for real-world applications.

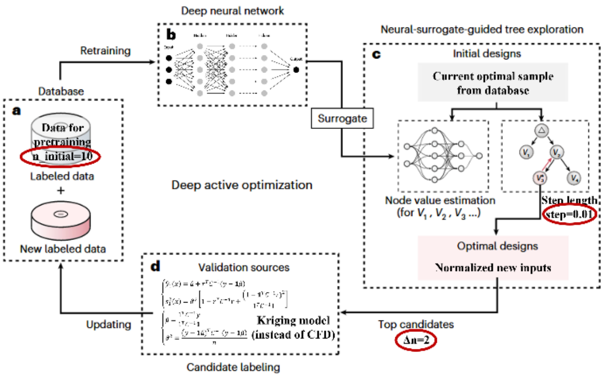

Figure 1. Architecture of DANTE.

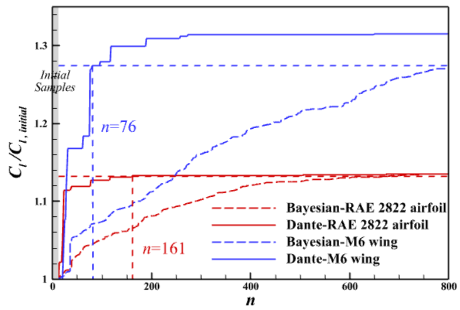

Figure 2. Optimization process of C_l.

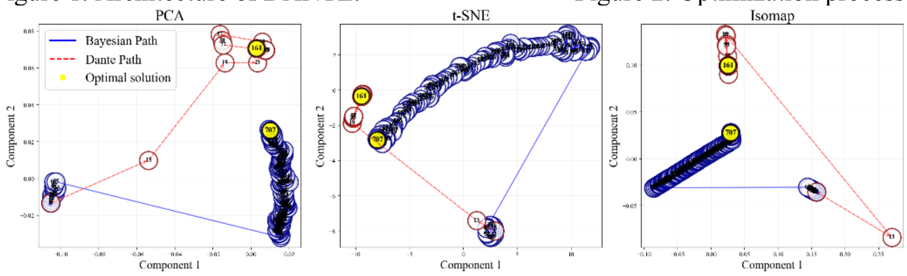

Figure 3. Optimization paths of different methods for RAE 2822 airfoil.

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Trajectory Control for Obstacle Avoidance of Flexible Manipulators Based on Spatio-Temporal Attention

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Flexible manipulators are widely used in advanced fields such as intelligent manufacturing, aerospace, and precision medicine due to their fast response, lightweight structure, and high flexibility. However, complex and dynamic working environments require manipulators to autonomously avoid moving obstacles, while structural flexibility introduces deformation and vibration during motion, which significantly increases the risk of collision. To enable flexible manipulators to accurately avoid dynamic obstacles while executing prescribed motion tasks, this paper proposes an integrated trajectory control method for obstacle avoidance based on a spatio-temporal attention mechanism. A local obstacle avoidance planning model is first constructed using the spatio-temporal attention mechanism. By performing temporal modeling and spatial weight allocation on the historical motion information of multiple dynamic obstacles, the model adaptively identifies key obstacles that have significant influence on the manipulator motion and predicts their future motion trends within a receding horizon, thereby generating short-term collision-free reference trajectories at the end-effector level. The planned end-effector trajectories are then transformed into ideal joint angle sequences that satisfy joint constraints through inverse kinematics mapping and trajectory interpolation. Finally, the obtained ideal joint angles are fed into a deep reinforcement learning-based tracking control framework that combines deep learning with the physical model of the flexible manipulator to predict joint driving torques. Simulation results demonstrate that the proposed method can effectively avoid dynamic obstacles and achieve satisfactory control performance, thereby improving the environmental adaptability and operational efficiency of flexible manipulators.

Keywords:
Dynamics model; Obstacle avoidance path planning; Trajectory tracking; Spatio-temporal attention mechanism; Deep reinforcement learning.

Acknowledgements
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Reconstructing High-resolution Tidal Fields from Sparse Sensor Data Using a Pretrained Spatiotemporal Generative Model

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High-resolution nearshore tidal information is essential for port operations, coastal management, and disaster response, particularly during extreme weather events [1]. However, the sparse spatial distribution of tide-gauge stations poses a fundamental challenge for obtaining the detailed full-field data needed for informed decision-making. To overcome this limitation, we propose a novel Tidal-field Generative Reconstruction Framework (TGRF) that integrates a pretrained deep learning model with sparse in-situ observations. The framework first learns the underlying spatiotemporal evolution patterns of tidal dynamics from historical data in an unsupervised manner. Subsequently, during the reconstruction stage, it assimilates real-time measurements from sparse gauge networks to generate physically consistent, high-resolution tidal fields. Using the complex coastal waters of Hong Kong as a case study, we validate the framework under both normal tidal conditions and two major typhoon events, Hato (2017) and Mangkhut (2018). Comparative analyses against baseline studies demonstrate that TGRF consistently outperforms existing approaches. Notably, it accurately reproduces the critical spatial structures and peak storm surge responses during the typhoons, highlighting its potential as a powerful tool for coastal monitoring and hazard mitigation.

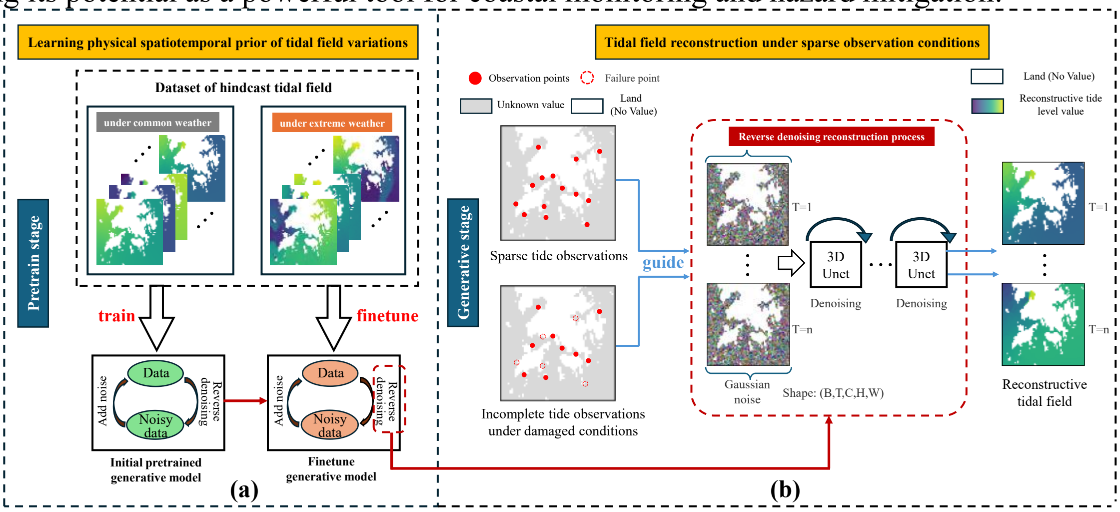

Figure 1. Diagram of Tidal-field Generative Reconstruction Framework (TGRF)

Acknowledgements
The study was financially supported by NSFC Key Project #52439001 and RGC/TRS Project #T22-607/24N. The authors appreciate the sharing of hindcast wave simulation dataset by Professor Alessandro Stocchino of PolyU.

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Data-Assimilated Physics-Informed Neural Networks for High-Reynolds-Number Cylinder Wake Flows: Overcoming Optimization Pathologies via Sparse Observations

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While Physics-Informed Neural Networks (PINNs) have emerged as a powerful deep learning framework for synthesizing observational data and partial differential equation (PDE) constraints, their application to strongly non-linear, transient dynamics at high Reynolds numbers remains challenging. Conventional PINNs often suffer from training pathologies, including spectral bias and causality violations, which severely hamper their predictive accuracy in chaotic systems. This study proposes an enhanced PINN framework to simulate the two-dimensional vortex shedding behind a circular cylinder at *Re*=500. Building upon state-of-the-art training architectures—incorporating Random Fourier Feature embeddings, Random Weight Factorization (RWF), and temporal causal training strategies—we further integrate sparse observational data into the multi-task loss function. While recent optimized PINN pipelines have successfully captured vortex shedding at *Re*=100, pushing the boundary to *Re*=500 introduces pronounced non-linearities that purely physics-driven optimization struggles to resolve. Our results demonstrate that incorporating sparse measurements effectively anchors the gradient descent trajectory, accelerating convergence and significantly enhancing the predictive accuracy of both velocity and pressure fields. The proposed methodology establishes a highly efficient, robust baseline for complex computational fluid dynamics (CFD) problems, demonstrating the critical synergy between advanced PINN architectures and sparse data assimilation.

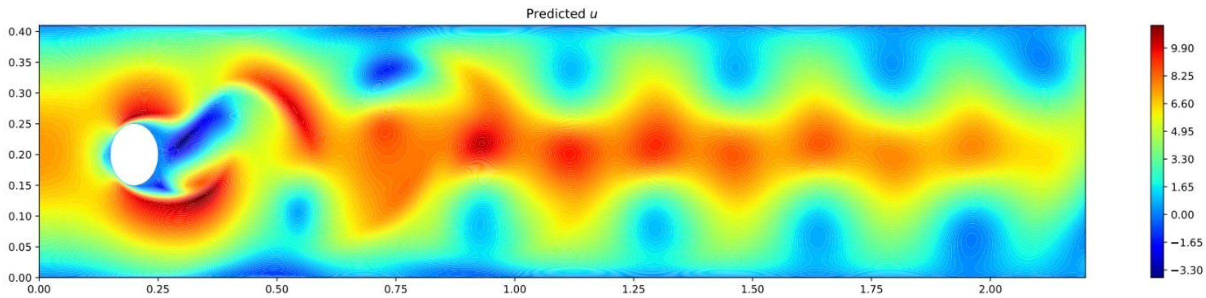

Figure 1. Navier-Stokes flow around cylinder: Predicted velocity field and pressure at the last time step.

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Parallel Session D2

Taming the Chaos: A Non-intrusive Machine-learning Framework for Debiasing Climate Emulations and Quantifying Rare Event Statistics

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Associated with the rapidly changing climate, the frequency and severity of extreme weather events have been increasing over the past decades. Since performing fully-resolved climate simulations is computationally intractable, stakeholders and policymakers must rely on coarse models or emulators to quantify the risk for extremes. However, coarse models suffer from inherent bias due to the ignored "sub-grid" scales. In this work, we aim at developing data-driven correction operators for coarse scale emulators. Previous efforts have attempted to train such operators by merely matching the statistics. Nevertheless, this approach falls short with events that have longer return period than that of the training data, since the reference statistics have not converged. To overcome such a limitation, we introduce a dynamical systems approach where the correction operator is trained using reference data and a coarse model simulation nudged toward that reference [1]. This framework is applied to debiasing a linear Gaussian stochastic emulator, which is constructed to accurately capture the second-order statistics of the ERA5 data [2]. With the nonlinear correction, the predicted higher-order moments of the local climate variables, including wind speed, temperature, and humidity, are more accurate than the free-running emulator. The non-Gaussian probability distributions are better estimated, particularly for the tails that correspond to extreme events with long return periods. We will also discuss the potential application of this framework to other emulators or coarse climate models.

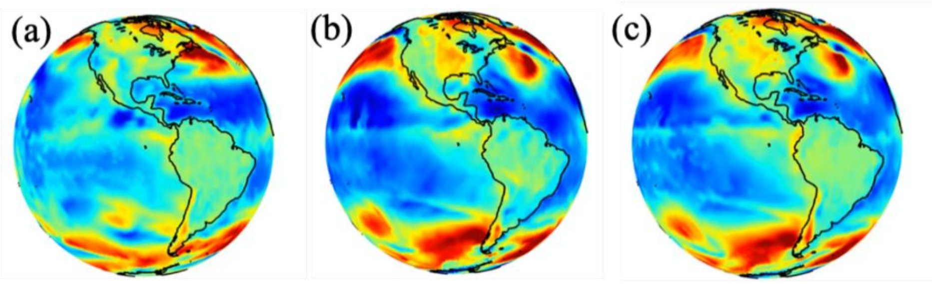

Figure 1. A snapshot of the zonal wind component, acquired from (a) free-running earth system simulation; (b) realistic observation data; (c) nudged earth system simulation that facilitates the training process of a ML model.

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Method for Identifying Vortex-Induced Vibration Anomalies in Transmission Tower Components Based on Machine Vision

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With the rapid development of China's economy, the electricity demand has increased dramatically, leading to the widespread application of ultra-high voltage transmission towers designed for large-capacity, long-distance power transmission. Under wind loads, circular components of transmission towers are highly susceptible to abnormal vortex-induced vibrations (VIV), which can cause fatigue damage to components, weld cracking at joints, bolt loosening, and ultimately threaten the operational safety of tower structures. The abnormal VIV of tower components is often sudden and temporary, making it difficult to detect promptly with existing maintenance methods. Moreover, it is challenging to assess quickly and accurately during routine inspection. Therefore, this study proposes a target-free identification method for capturing the dynamic response of tower components. Using a portable camera to record the abnormal VIV process of components, stable extraction of edge grayscale features enables rapid identification of the dynamic response of tower VIV. The results indicate that in the time domain response, VIV exhibits significant multi-stage displacement variations, namely the excitation stage, stable stage, and decay stage. In the frequency domain response, the VIV process shows a notable frequency stabilization phenomenon. In addition, to reduce the difficulty of on-site environmental calibration, a relative displacement-based early warning indicator for abnormal VIV is established, providing a quick and effective assessment tool for power line inspectors. In summary, the machine vision-based method provides a novel approach for detecting and evaluating abnormal conditions in transmission tower components. This method demonstrates significant advantages, including high accuracy, multi-point measurement capability, and low cost. In the future, by integrating fixed camera devices, this approach can further enable the timely identification of abnormal vortex-induced vibrations.

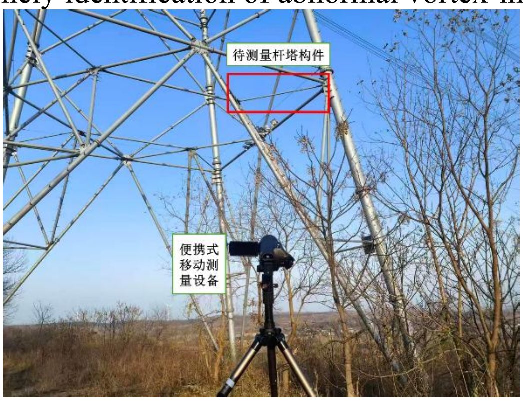

Figure 1. Measurement of the VIV in field experiments.

Acknowledgements
The authors wish to thank the National Natural Science Foundation of China (Grant No.52508536), Natural Science Foundation of Jiangsu Province (Grant No.20251265) and Jiangsu Funding Program for Excellent Postdoctoral Talent (Grant No. 2025ZB636).

Research on and Modification of Turbulence Models for Adverse Pressure Gradients Based on Symbolic Regression

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The existing Reynolds-averaged Navier–Stokes (RANS) turbulence models are fundamentally based on the assumptions of local equilibrium and mixing length. Under adverse pressure gradient (APG) conditions, these assumptions gradually break down, leading to a deterioration in predictive accuracy. To address this issue, the present study employs symbolic regression (SR) to derive new formulations for the production-to-dissipation ratio P_k/ε and the mixing length under APG conditions. These formulations are incorporated as corrections into the original Menter SST model, resulting in two modified models specifically tailored for separated flows[1-2]. SR, a classical machine learning technique, enables the selection of variables and operators guided by existing turbulence theory and physical intuition, thereby ensuring the interpretability of the resulting expressions. The generality and accuracy of the SR-derived formulas are assessed through comparisons with high-fidelity data. By more accurately capturing the P_k/ε balance and the wall-normal eddy viscosity distribution, the modified models provide better-resolved turbulent quantities and wall shear stress, effectively mitigating the premature separation issue inherent in the original Menter SST model.

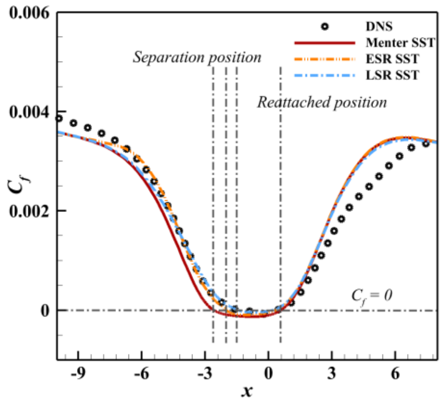

Figure 1. Comparison of skin friction coefficient distributions predicted by the original and modified SST.

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Ultrasonic measurement of ice layer melting on the surface of aircraft skin

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This study addresses the critical challenge of real-time monitoring for local ice-layer debonding during thermal protection system (TPS) operation. We propose an ultrasonic method based on multilayer acoustic transmission theory to detect melting progression at the skin-ice interface. A five-layer acoustic model (skin, water film, ice-water transition layer, ice layer, air) was established. Ultrasonic pulses with varying center frequencies served as excitation sources, and interfacial echo signals were obtained via numerical simulation. A dedicated signal processing algorithm was developed to extract characteristic parameters from the raw echoes, specifically proposing the ultrasonic reflection coefficient at the skin-ice interface as an indicator for melting degree. An ultrasonic detection system was built to measure ice-melting progression under active electrical heating was experimentally validated in subzero environments across clear ice, mixed ice, and rime ice conditions. Theoretical results demonstrate that the formation of a thin water film during melting alters the ultrasonic reflection coefficient at the skin-adherent interface, enabling melting assessment. A reflection coefficient threshold >0.8 was established as the ice-melting criterion. Higher frequencies detected thinner water films. Experimentally, the system successfully generated debonding signals during the initial phase of electrical heating activation for all tested ice types. This work provides insights into ultrasonic pulse propagation at the skin-ice interface under thermal protection and demonstrates a methodology with significant potential for reducing TPS energy consumption through precise melting state monitoring.
Keywords: Ice-melting, Ultrasonic detection, Reflection coefficient, Multilayer model

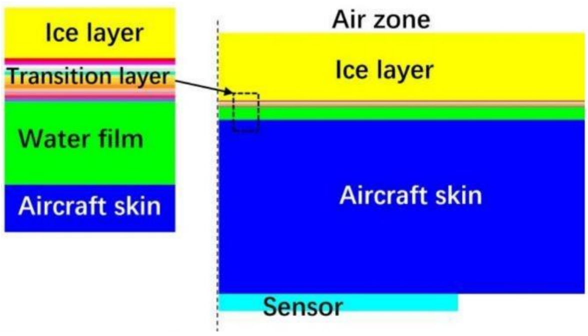

Figure 1. Modeling of Ultrasonic Propagation in Multi-layer Media.

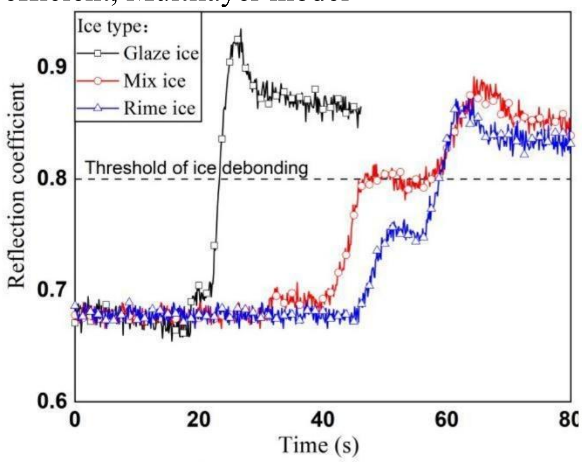

Figure 2. Ultrasound measurement results of the interface melting of different types of ice layers.

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Parallel Session E1

Research on the high-speed water-entry characteristics of different head projectiles based on two-way fluid-structure interaction

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The dynamic response of the projectile structure during high-speed water-entry is directly related to whether the projectiles can safely enter the water and the stability of the movement after entering the water. High-speed supercavitating projectiles are subjected to significant impact load during water-entry, and significant structural deformation occurs. There is mutual influence and interaction between structural deformation and flow field. The conventional simulation analysis method based on rigid body assumption is no longer applicable. In order to deeply analyze the role of projectile structure deformation in the process of high-speed water-entry and its interaction with fluid dynamics, based on the theory of fluid mechanics and structural dynamics, a two-way fluid-structure interaction numerical model of projectile high-speed water-entry is established by coupling fluid solver and structure solver. The two-way fluid-structure interaction method is used to simulate the supercavitating flow characteristics and structural deformation characteristics of cylindrical flat-head and hemispherical-head projectiles during water-entry. By comparing the calculation results of the fluid-structure interaction model and the rigid body model, the influence of the structural deformation of the supercavitating projectile on the hydrodynamic load is obtained. The results show that : 1) The head shape of the projectile has a significant effect on the shape of the supercavity and the hydrodynamic load during the water-entry of the high-speed projectile. 2) The structural deformation of high-speed projectile during water-entry has a certain influence on the shape of the supercavity and hydrodynamic characteristics.

Keywords

High-speed, supercavitating projectiles, cylindrical flat-head, hemispherical-head, two-way fluid-structure interaction, shape of the supercavity

Acknowledgements

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Quantifying the Role of Thermoelectric Magnetohydrodynamic Process in Keyhole Pore Formation during Laser Powder Bed Fusion

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The application of a static magnetic field during Laser Powder Bed Fusion (LPBF) has recently emerged as a promising method to reduce keyhole-induced porosity, primarily through the thermoelectric currents generated by the Seebeck effect [1,2]. However, the underlying physical mechanisms by which these magnetohydrodynamic forces alter the complete cycle of keyhole formation and pore entrainment remain poorly understood. In particular, the complex interplay between the temperature-gradient-driven currents and the resulting Lorentz forces on melt pool dynamics and keyhole stability has yet to be quantified.

To address this gap, we have developed a high-fidelity thermo-magneto-hydrodynamic framework within OpenFOAM [3] that fully couples thermal [4], fluid flow [4], and electromagnetic physics. Our simulations elucidate the control mechanisms by which a horizontal magnetic field influences keyhole behavior. We provide quantitative evidence for three key phenomena: (1) the stabilizing effect of the Seebeck-induced Lorentz force on the keyhole interface, which dampens capillary-driven fluctuations; (2) the mechanism responsible for the observed reduction in time-averaged keyhole depth under a static field; and (3) a direct correlation between magnetic field strength and the suppression of pore detachment. This work offers the first detailed, quantitative assessment of how thermoelectric magnetohydrodynamic phenomena govern pore evolution, providing a robust physical basis for process optimization in defect-free LPBF.

Acknowledgements

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Study on the Acoustic Propagation in Impact Ice Based on Biot Theory

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When the aircraft passes through low-temperature and high-humidity clouds during flight, porous impact ice different from frozen ice will be generated and accumulated on the windward surface. The macro performance of its porous characteristics is icing density, which is a key parameter affecting the accuracy of icing numerical simulation and aircraft icing protection design. Based on the Biot porous media theory, this paper focuses on the propagation characteristics of acoustic wave in porous impact ice, exploring the acoustic response law under different porosity, permeability and ultrasonic excitation frequency, and summarizes the application scope of biot porous media in the field of aircraft icing. The results show that the propagation characteristics of sound waves in porous ice have a good linear relationship with porosity, and permeability has a significant effect on slow wave attenuation. The frequency curve obtained in this study can provide a reference for frequency selection in the subsequent refined ultrasonic measurement of impact ice density.

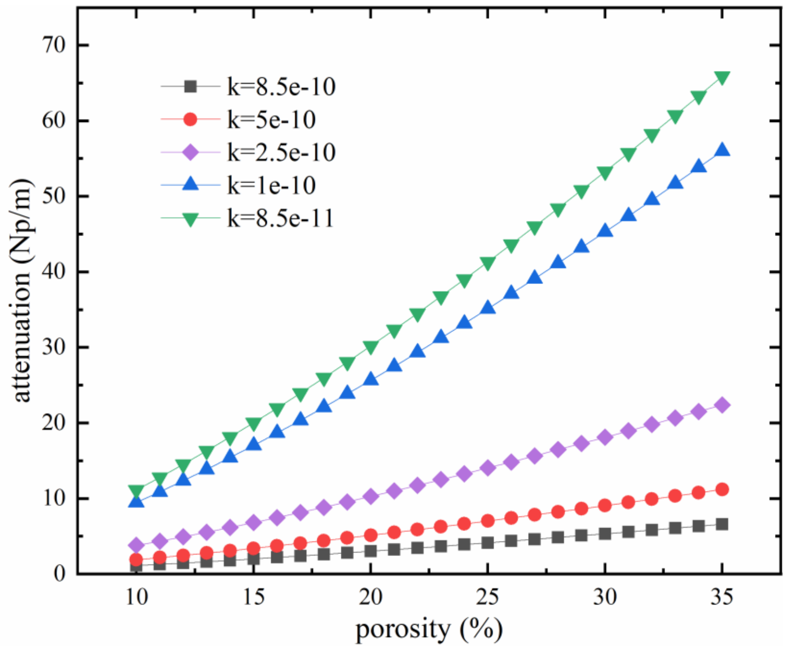

Figure 1. Porosity vs attenuation relationship under different permeabilities.

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Experimental Study of Fabric Evolution during Multiple Liquefaction of Toyoura Sand

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Multiple liquefaction is a phenomenon that the soil liquefies multiple times during a sequence of earthquake shaking. Field observation shows that once the soil is liquefied, it may have much lower resistance to a subsequent liquefaction event. Although the drastic change in multiple liquefaction resistance is often attributed to the evolution of soil fabric, there is a lack of direct observation to support the scientific understanding of this phenomenon. This study conducted a series of cyclic triaxial tests on Toyoura sand. Bender elements are used to measure the evolution of small-strain shear moduli in the horizontal and vertical directions (G_h and G_v) during the multiple liquefaction process. The variation of small-strain shear moduli represents evolution of soil fabric, in particular rearrangement of inter-particle contacts during the complicated liquefaction- reconsolidation-reliquefaction process, which is found be to directly related to the reliquefaction resistance.

Keywords: Multiple liquefaction; Soil fabric; Small-strain shear modulus

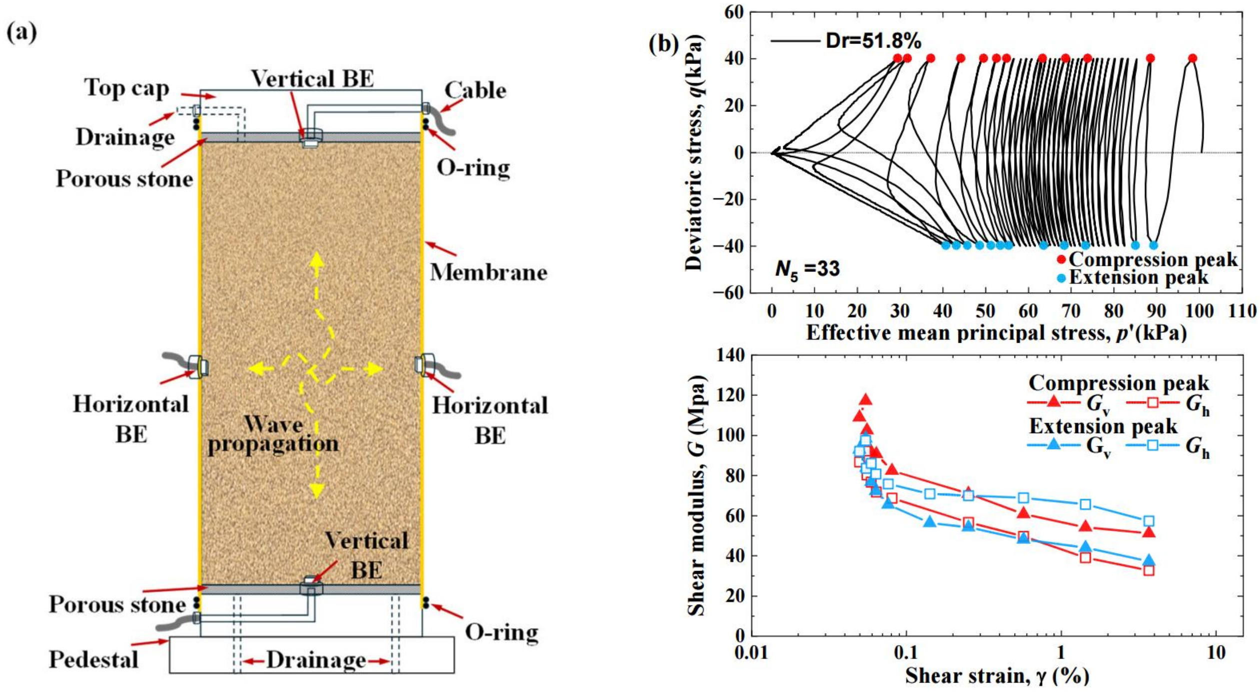

Figure 1. (a) Triaxial tests with bender elements, (b) Evolution of small-strain shear modulus during liquefaction

Acknowledgements

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氧化对镍基单晶合金超高周疲劳裂纹萌生与扩展行为的影响

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当前，对于氧化作用在超高周疲劳范围内对镍基单晶高温合金裂纹萌生与扩展行为的影响仍缺乏系统认识。围绕这一问题，设计了新型缺口板状超声疲劳试样，并在 1000 °C 条件下开展超高周疲劳试验；同时结合准原位观测手段，对裂纹萌生与扩展过程进行连续跟踪。结果表明，在氧化环境作用下，裂纹优先于表面缺口根部萌生，并以张开型（Mode I）形式扩展。断口形貌可划分为三个典型区域：萌生区、化学小裂纹扩展区以及长裂纹扩展区。其中，化学小裂纹扩展区表面被大量氧化产物覆盖，而长裂纹扩展区则以宏观疲劳弧线和微观疲劳条带等典型疲劳特征为主，氧化产物明显减少。

裂纹萌生及化学小裂纹扩展阶段的氧化行为演变，与合金元素发生氧化所需的临界氧分压密切相关。萌生阶段裂纹尖端氧化产物呈现出由内向外 $(Ni,Co)O$、Cr_2O_3以及颗粒状 Al_2O_3的多层复合结构。当进入化学小裂纹扩展区时，裂纹尖端氧化物已转变为以 Al_2O_3为主的连续、单层氧化物形貌，同时裂纹尖端局部区域的 γ'出现平行于裂纹扩展方向的筏化形貌。随着裂纹向内扩展，裂纹尖端处氧分压逐渐降低，最终仅临界氧分压最低的 Al 能够持续形成氧化物。

从寿命分配来看，裂纹萌生阶段所占比例低于 2%，而化学小裂纹扩展阶段占总寿命的 90%以上，表明该阶段主导整体损伤演化过程。在化学小裂纹扩展区，受氧化诱导裂纹闭合效应影响，裂纹扩展速率近似保持恒定，与应力强度因子范围的相关性较弱，裂纹扩展行为主要受氧化反应速率控制。当有效应力强度因子超过临界阈值后，氧化诱导裂纹闭合效应逐渐减弱并最终消失，裂纹扩展进入长裂纹阶段，此时扩展机制转变为由循环塑性变形主导。

Acknowledgements
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Parallel Session E2

Diamond-Based 3D Rotation Sensing for Force Measurement

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Cellular traction forces are conventionally measured by tracking the displacement of beads or micropillars, which is limited by optical diffraction and the assumptions inherent in the Euler-Bernoulli beam theory. We here introduce an alternative method that quantifies force via direct measurement of rotational angles, employing fluorescent nanodiamonds as three-dimensional orientation markers embedded within the system. Specifically, by integrating optically detected magnetic resonance (ODMR) with laser polarization modulation (LPM), we determine the complete three-dimensional orientation of nanodiamonds attached to PDMS micropillars with sub-degree precision (~0.5°). This angle-based measurement framework circumvents the resolution limits of displacement tracking and remains valid for stocky beams or in scenarios involving large deformations. Finite-element simulations reveal that our method reduces force estimation errors by at least 10% compared to conventional displacement-based approaches. We also successfully capture multidimensional pillar deformations—including bending and twisting—that are inaccessible to conventional displacement-only method. Taken together, our work establishes diamond-based angular force microscopy as a high-precision platform for mechanobiology.

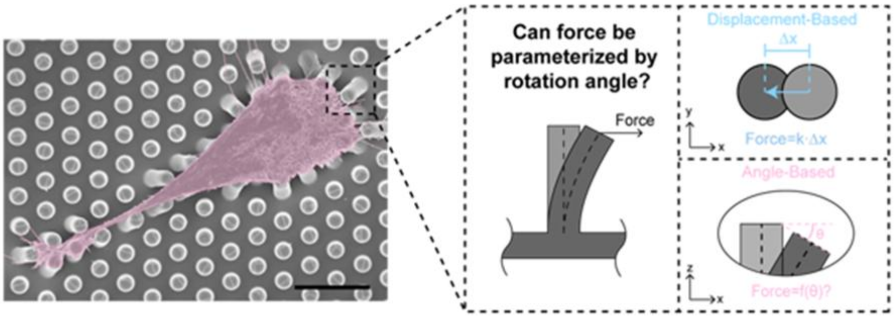

Figure 1. Rotation angle as an alternative mechanical readout for cellular force measurement.

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A Modular, Bubble-infused Hydrogel Wearable Ultrasound Device for Minimally Invasive Biochemical Monitoring

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Miniaturized wearable ultrasound technologies enable accurate monitoring of diverse physiological information, yet the detection of biochemical metrics remains a daunting task due to the “acoustic invisibility” of small molecules such as glucose. To bridge this gap, we establish a mechano-acoustic transduction mechanism based on bubble resonance modulation. Guided by this mechanism, we engineered a “Core-Shell Cell” (CSC) to translate biochemical stimuli into acoustic signatures. The CSC features a bubble-embedded hydrogel core encapsulated by a stimuli-responsive hydrogel shell (e.g., glucose-responsive PBA or pH-responsive PAA-Chitosan). Upon exposure to target biomarkers, the shell swells, exerting compressive stress on the core and inducing a quantifiable shift in the transmitted ultrasound frequency spectrum. Implementing this strategy, we present a modular, wearable ultrasound platform for minimally invasive biochemical monitoring. This platform integrates reusable wearable ultrasound units with a disposable, internally hollow microneedle array that houses the CSC, which serves as the critical interface between ultrasound sensing and biochemical analysis. We demonstrate the versatility of this platform through two distinct monitoring paradigms. First, configured for pH monitoring, the platform precisely quantifies physiological pH level within the range of 6.5–7.7, capturing the critical pathological window of diabetic ketoacidosis (DKA). Second, in the glucose monitoring paradigm, we established a correlation between glucose rising rates and frequency shifts, enabling hyperglycemic alerts without the need for steady-state equilibrium. Validated by chemo-mechanical coupling model analysis and in vitro characterization, this work effectively endows wearable ultrasound with “biochemical vision”, establishing a universal strategy for diverse biochemical profiling.

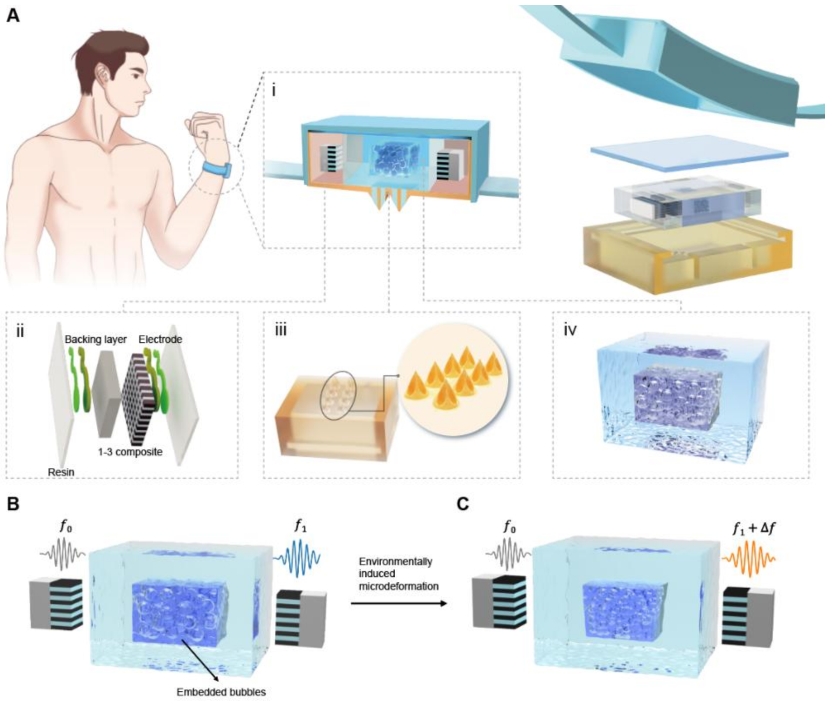

Figure 1. Architectural design and concept of the proposed device.

The infiltration paradox: how pore-gas pressure controls early slope failure under rapid surface hydraulic loading

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The assumption of atmospheric pore-gas pressure in slope stability analysis can break down under rapid surface hydraulic loading, such as flash floods or wave overtopping. In these events, a transient water head builds up faster than the internal groundwater system can respond, trapping and compressing pore-air. This study investigates the role of evolving pore-gas pressure on failure timing using a three-phase hydro-mechanical material point method (MPM) that couples large deformation with immiscible water-gas flow. We simulate a transient surface water head ramping from 0 to 2.5 m on a partially saturated slope, comparing the gas-coupled model against a reference model with prescribed atmospheric pressure. Simulation reveals a distinct regime shift in failure behaviour. For low heads (< 0.5 m), both models predict nearly identical onset times. Above this threshold, resolving gas pressure consistently advances instability, with onset-time differences reaching ~6 seconds at the highest head. This occurs despite gas coupling suppressing infiltration and creating a shallower wetting front, a phenomenon we term the "infiltration paradox." We resolve this paradox by showing that gas compression elevates pore pressures locally within the developing shear band, shifting the effective stress path toward failure more rapidly than infiltrating water alone. These findings provide a quantitative framework for determining when coupled gas-phase dynamics are essential for accurate prediction of failure timing under extreme hydraulic events.

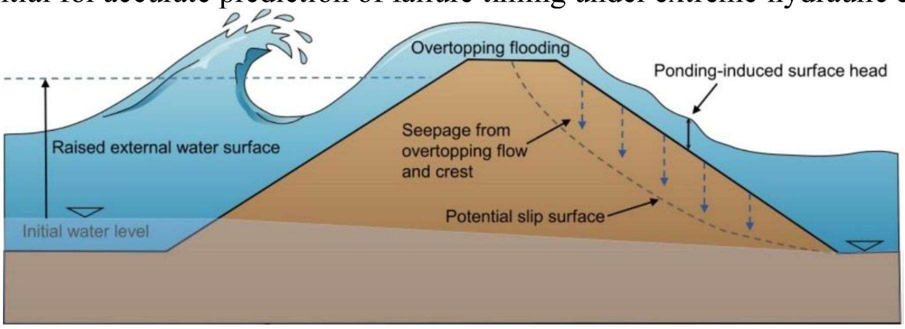

Figure 1. Conceptual illustration of a partially saturated slope subjected to a transient surface water head (e.g., from rapid overtopping). (Adapted conceptually from Johnston et al., 2021; and Zhou et al., 2022).

Acknowledgements

The study was financially supported by NSFC #52439001, RGC/GRF #16217225 and RGC/TRS #T22-607/24N.

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In Situ Ice Monitoring on Aircraft wings Using a Flexible Ultrasonic Transducer

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In practical scenarios, surfaces such as aircraft wings, engines, unmanned aerial vehicles (UAVs) and wind turbine blades are all susceptible to freezing. Ice formation not only leads to energy dissipation in aircraft but can also result in flight accidents under severe conditions. To mitigate the hazards associated with ice, modern aircraft are equipped with anti-icing systems. However, activating these systems without knowledge of the ice accumulation level consumes a significant amount of onboard energy. Effective ice detection is a critical prerequisite for reducing the energy consumption of anti-icing systems and ensuring flight safety. Currently, various methods for ice detection exist, such as resonant detection, optical detection and ultrasonic detection. These diverse approaches enable customized solutions to meet specific application requirements. As a high-precision, non-destructive testing method, ultrasonic detection holds significant potential in the field of ice detection. However, existing ultrasonic transducers are brittle and cannot conform to the surfaces of aircraft or drones.

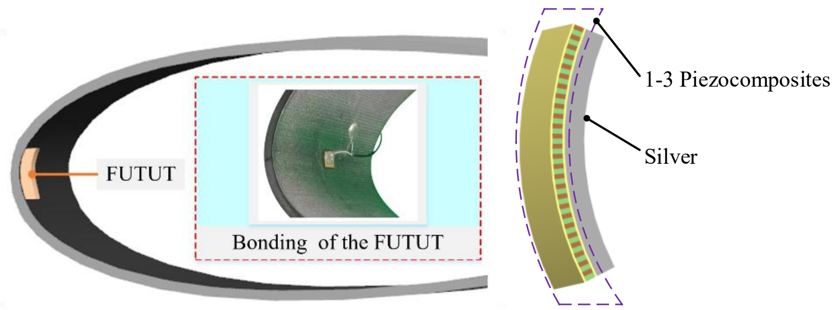

Figure 1 Schematic of FUTUT bonding and detailed structure

This paper presents a flexible ultrasonic transducer (FUT) with high sensitivity, designed for in situ ice monitoring on irregular surfaces. The FUT employs a 1-3 piezocomposite material, which is processed using a cutting-filling technique to impart flexibility to the sensor. By designing the acoustic impedance of the piezocomposite, the sensor's structure has been optimized. Furthermore, careful selection of the central frequency ensures the sensor's resolution in detecting ice thickness. The FUT's flexibility is tested on the leading edge of a scaled NACA 0024 wing model, and dynamic experiments conducted in an icing wind tunnel (IWT) reveal its capability for real-time monitoring, with a detection limit of 0.29 mm and a maximum measurement error of 6.19%. These results underscore the FUT's promise for applications in ice detection on curved surfaces.

Acknowledgements

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A Strain-insensitive Dual-stopband Flexible 3D FSS for Stable Electromagnetic Performance under Mechanical Stretching

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Abstract:

A key challenge for flexible frequency selective surfaces (FSSs) is maintaining stable electromagnetic (EM) performance under mechanical deformation. To conform to non-developable curved surfaces, flexible FSSs must simultaneously achieve high deformability and robust EM stability, while the increasing demand for multi-band interference suppression further increases design complexity. Here, we present a dual-band flexible three-dimensional (3D) FSS that integrates a square ring and an S-shaped cross dipole to generate two distinct stopbands. A buckled metallic architecture, combined with a stretchable elastomer substrate, mitigates strain effects and enables conformal integration with curved geometries. Experiments confirm stable dual-stopband filtering over a biaxial tensile strain range of 0% to 12.4%, with resonance frequencies maintained at approximately 3.7 GHz and 5.7 GHz. The underlying strain-insensitive response is elucidated through mechanical simulations, full-wave EM simulations, and equivalent circuit analysis. This work provides a generalizable design strategy for achieving strain-resilient dual-band flexible FSSs, offering practical potential for flexible electronics, wireless sensing, and EM stealth applications.

Young Scholars Forum

Session F1

Structural Designs, Mechanics and Multi-functional Applications of Advanced Multi-scale composites

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在本工作中，作者提出了仿蚕茧连续纤维毡结构设计策略，发展了聚合物基，陶瓷基连续复合纤维及其毡结构的连续喷射纺丝制备工艺，获得了力学性能、电学性能以及热学性能优异的多功能纤维毡，采用分子动力学模拟方法以及原位力学测试方法揭示了这类结构的力学增强和失效机制，在此基础上，制备获得了性能优异的这类毡结构增强复合材料，上述工作为先进纳米复合材料的结构设计及应用奠定了理论和实验基础。

Figure 1. 超轻氧化物连续陶瓷纤维毡结构.

Topological Defects Mediate Transport Phenomena in Active Soft Solids

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It is well established that topological defects play a crucial role in determining the material properties of crystalline solids. Recently, there has been growing interest in understanding the behavior of such defects in active soft solids—including biological tissues, embryos, and biofilms. In these living materials, self-propelled units such as cells can self-organize into long-range ordered structures, either in their spatial arrangement or orientational alignment, leading to the formation of crystalline or liquid-crystalline phases. In this talk, we explore how the frustration of these orders, characterized by topological defects, governs transport phenomena in active soft solids. Specifically, we employ simulations to investigate the formation and healing of disclinations during cell transport. By comparing with various colloidal crystal models, we identify the distinct roles of cell adhesion, cell activity, and many-body interactions in the defect-healing process. Our findings provide insights into cellular transport mechanisms that preserve tissue integrity.

Acknowledgements
The authors wish to thank General Research Fund supported by Research Council of Hong Kong.

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Strain Gradient Mediated Decoupling of Thermal Conductivity and Anisotropy in BentGa2O3

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Ultra-wide bandgap semiconductors such as β-Ga_2O_3 are promising for next-generation electronics but are limited by intrinsically low and highly anisotropic thermal conductivity (k). Here, we employ machine-learning-based interatomic potentials and Boltzmann transport calculations to systematically compare the effects of uniform strain and strain gradient (η_{sg}) on the thermal transport of β-Ga_2O_3 nanomembranes. We find that realistic η_{sg}—as from bending or epitaxy—suppresses k by up to 52% in 10-nm films, exceeding equivalent uniform strain by over 1.5 times and yielding even stronger k reduction than previously reported for Si, BAs, and SiC. Importantly, uniaxial η_{sg} enables pronounced anisotropy tuning, with the in-plane k ratio (k_b/k_a) enhanced by ~50% or reduced by ~40%, surpassing uniform strain effects. Our results highlight the exceptional efficacy of strain gradient engineering for manipulating thermal transport and anisotropy in flexible β-Ga_2O_3 devices.

Vibration-coded metamaterials for intelligent predictive maintenance of low-altitude aircraft

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Abstract: Intelligent predictive maintenance of low-altitude aircraft relies on accurate vibration sensing, yet current systems face three key limits: the need for many sensors to locate faults, a trade-off between sensitivity and bandwidth, and the mismatch between continuous mechanical motion and discrete high-rate sampling. Here we introduce vibration-coded mechanical metamaterials that embed information processing directly in elastic dynamics to address these problems at the structural level. First, we design information-driven elastic programmable metamaterials that reshape wave propagation so that the position and strength of a vibration source can be inferred from a single mechanical measurement point. Second, we realize purely mechanical frequency-division multiplexing metamaterials that split broadband vibrations into multiple narrow bands, overcoming the usual sensitivity–bandwidth trade-off in vibration sensing. Third, we create wave-based analogue computing metamaterials that perform spectral operations on propagating elastic waves, reducing the impact of the mismatch between continuous dynamics and discrete sampling. Experiments and simulations on representative low-altitude aircraft structures show that these dynamics-guided metamaterials enable robust source localization, wide-band yet sensitive detection, and efficient spectrum extraction. This mechanics-centric sensing strategy offers a scalable route to intelligent, vibration-based health monitoring of next-generation low-altitude aircraft.

Young Scholars Forum

Session F2

Ultrathin Seed Wing with Heterogeneous Structure for Highly Efficient Dispersal of African Tulip Tree

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To colonize new habitats, plant seeds have evolved specialized structures for wind dispersal. The African tulip tree produces ultrathin winged seeds whose wing region is mostly a single-cell layer, with the thinnest part only ~0.4 μm thick. Despite contributing only ~25% of the seed mass, the wing covers about 90% of its area. From a mechanics perspective, the ultrathin membrane is reinforced by heterogeneous vein-like structures, forming a lightweight yet mechanically stable system that maintains wing extension in turbulent airflow and suppresses circumferential fracture. In addition, the flexible film can deform to conform to uneven wet surfaces, facilitating attachment to water-rich substrates for germination. Inspired by this natural lightweight–stiffness–toughness balance, we designed a bio-inspired passive micro-flier that reproduces these mechanical principles for multifunctional aerial systems.

Figure 1. Seed of an African tulip tree attached on a fingertip, featuring a heart-shaped core in the middle and an extending filmy wing

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Shape memory polymer-based switchable bio-inspired microstructured dry adhesives

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To resolve the inherent conflict between strong adhesion and easy detachment, this study proposes a switchable bio-inspired microstructured adhesive based on shape memory polymers (SMPs). By utilizing the shape memory effect to dynamically modulate the material's modulus and contact area, the optimized formulation achieved superior performance on glass under a 200 kPa preload: a maximum adhesion strength of 525 kPa, a switching ratio of 5.4, and an adhesion-to-preload ratio of 2.625. Self-cleaning capabilities were validated with efficiencies reaching 90.30%. Theoretically, the study elucidated the buckling instability collapse mechanism and established an adhesion force model based on the bilinear cohesive zone model (CZM). The adhesive exhibited exceptional adaptability across various substrates (silicon, metals, glass), maintaining strengths of 238–525 kPa. Notably, adhesion variations on steel and aluminum surfaces with distinct roughness levels were limited to approximately 35%, and performance remained stable over 400 cycles. Finally, practical applications, including the grasping of diverse objects and the adhesive perching and relaunch of a UAV, demonstrated the material's potential for advanced robotic systems.

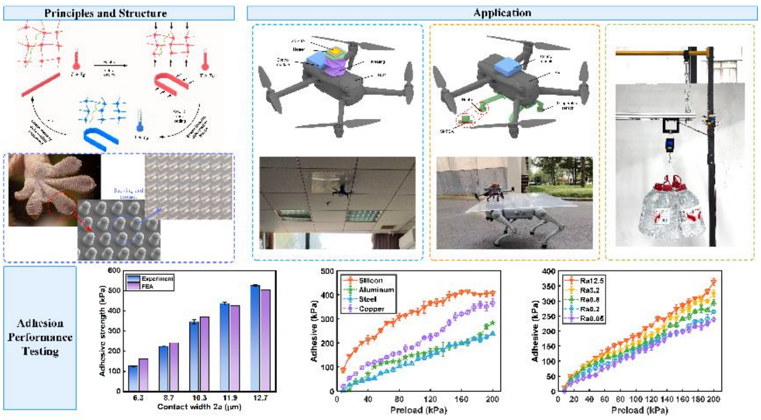

Figure 1. Design, performance evaluation, and practical applications of a switchable adhesives.

Acknowledgements

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Spinning Twisted Ribbons: When Two Holes Meet on a Curved Liquid Film

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The rupture of a liquid film, where a thin liquid layer between two other fluids breaks and forms holes, commonly occurs in both natural phenomena and industrial applications. The post-rupture dynamics, from initial hole formation to the complete collapse of the film, are crucial because they govern droplet formation, which plays a significant role in many applications such as disease transmission, aerosol formation, spray drying nanodrugs, oil spill remediation, inkjet printing and spray coating. While single-hole rupture has been extensively studied, the dynamics of multiple-hole ruptures, especially the interactions between neighbouring holes, are less well understood.

We recently found that when two holes 'meet' on a curved film, the film evolves into a spinning twisted ribbon before breaking into droplets, distinctly different from what occurs on flat films. We explain the formation and evolution of the spinning twisted ribbon, including its geometry, orbits, corrugations and ligaments, and compare the experimental observations with models. While our experiments are based on the multiple-hole ruptures in corona splash, the underlying principles are likely applicable to other systems.

Acknowledgements

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Synthesis-property relation of soft materials

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Study of synthesis-property relation is a fundamental challenge in materials science. Materials map the space of synthesis parameters to the space of properties. Both spaces have high dimensions and the map is non-linear. Here we study the synthesis-property map of soft materials. Emphasis is placed on how crosslinks and entanglements affect the stress-stretch curve of a polymer network. Polyacrylamide hydrogels synthesized by free radical polymerization are employed as a model system. The synthesis parameters include the crosslinker-to-monomer molar ratio and the water-to-monomer molar ratio of a precursor, as well as the polymer content of a hydrogel. Series of hydrogels are prepared and some of the hydrogels are further swollen in water to equilibrium or to a certain polymer content. For each hydrogel, the stress-stretch curve is measured, which gives four properties: modulus, stretchabiliy, strength, and work of fracture. Crosslinks lower the strength, but entanglements do not. By contrast, both crosslinks and entanglements increase modulus. A polymer network of dense entanglements and sparse crosslinks exhibits high modulus, strength, and swell resistance.

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Fourier Reduced Physics Informed Neural Operator for Solving Parametric PDEs in Computational Mechanics

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Parametric partial differential equations (PDEs) are the basic form in mechanics, playing as the governing equations for physic laws. Recently, physics-informed neural operators have emerged as a powerful learning framework for solving parametric PDEs, particularly in the area of computational mechanics. Physics-informed neural operators provide a learning framework of solution operators, which can be generalized for different values of parameters. In present work, we proposed a novel physics-informed neural operator for solving parametric PDES in computational mechanics. The proposed model is mainly constructed by a Hyper-Network and a main network. Two contribution are achieved by the proposed model:(1) The layered hypernetwork architecture that enables the parameter generation for each network layer; and (2) a frequency-domain reduction strategy is applied to significantly reduce the model parameters. The perfomance of the proposed model is demonstrated on four representative PDE problems, including Anti-derivative, Advection, Burgers and Diffusion-Reaction equations.The numerical experiments show promising results for our proposed model.

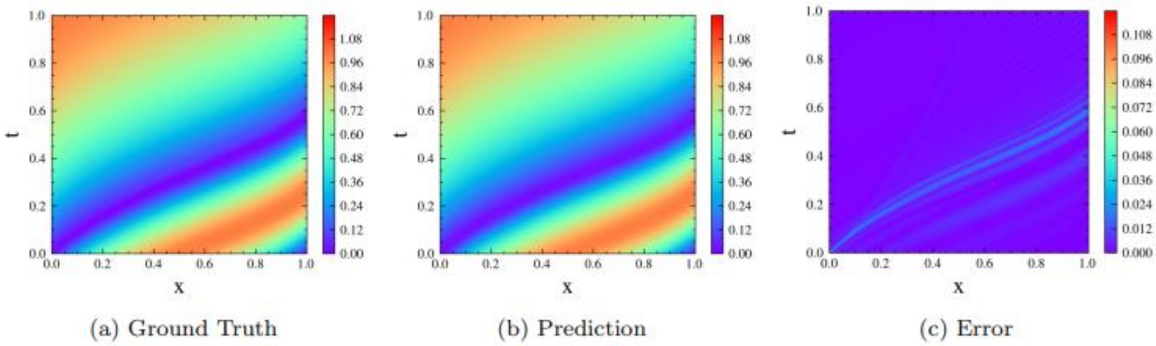

Figure 1. Analytical solutions and model predictions for advection equation.

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Style-constrained inverse design of microstructures with tailored mechanical properties using unconditional diffusion models

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Deep generative models, particularly denoising diffusion models, have achieved remarkable success in high-fidelity generation of architected microstructures with desired properties and styles. Nevertheless, these recent methods typically rely on conditional training mechanisms and demand substantial computational effort to prepare the labeled training dataset, which makes them inflexible since any change in the governing equations or boundary conditions requires a complete retraining process. In this study, we propose a new inverse design framework that integrates unconditional denoising diffusion models with differentiable programming techniques for architected microstructure generation. Our approach eliminates the need for expensive labeled dataset preparation and retraining for different problem settings. By reinterpreting the noise input to the diffusion model as an optimizable design variable, we formulate the design task as an optimization problem over the noise input, enabling control over the reverse denoising trajectory to guide the generated microstructure toward the desired mechanical properties while preserving the stylistic constraints encoded in the training dataset. A unified differentiation pipeline via vector-Jacobian product concatenations is developed to enable end-to-end gradient evaluation through backpropagation. Several numerical examples, ranging from the design of microstructures with specified homogenized properties to those with targeted hyperelastic and elasto-plastic behaviors, showcase the effectiveness of the framework and its potential for advanced design tasks involving diverse performance and style requirements.

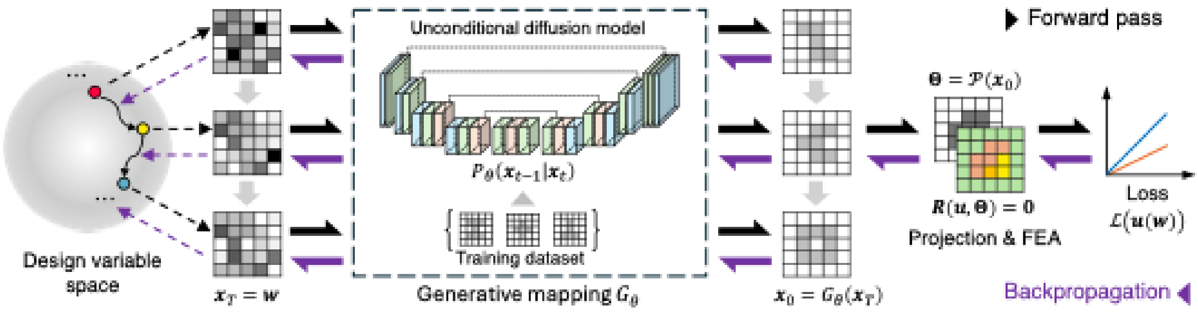

Figure 1. Overview of the method.

Young Scholars Forum

Session F3

Modeling the History Dependent Behavior of Viscoelastic Composites Using Recurrent Neural Operator

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Modeling the finite-deformation, history-dependent behavior of heterogeneous viscoelastic composites remains a challenge due to the complex interactions across multiple scales. High-fidelity methods, such as FE^2 methods, can capture the detailed physics of composites at mesoscopic scales, but are often computationally prohibitive. In this work, we propose a recurrent neural operator (RNO)-based framework that efficiently captures the multiscale viscoelastic response of composite materials under large strains. Data used for training the RNO model is generated by offline calculation at the level of representative volume element (RVE) and by the use of proper sampling method and neural network architecture, the RNO model is able to predict both the macroscopic stress and the evolution of internal state variables, achieving accurate and physically consistent results. The developed framework preserves key physical properties, such as objectivity and thermodynamic consistency, and enables flexible deployment across different loading rates and resolutions without retraining. The model was further validated through macroscopic examples, confirming the model's capability to capture complex path-dependent effective responses with high fidelity. This study demonstrates the potential of operator learning to transform multiscale modeling of complex materials, offering an efficient and scalable alternative to conventional approaches.

Rationalizing Polymer Networks with Hyperelasticity and Omniadhesion

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Stretchable materials with hyperelasticity (i.e., low hysteresis) and strong adhesion are needed in applications, but unifying the two contradictory mechanical properties is challenging. we propose rational design principles for polymer networks that simultaneously exhibit hyperelasticity and omnidirectional adhesion. First, we design *heterogeneous* networks composed of a viscoelastic adhesive surface layer and a hyperelastic non-adhesive bulk, where the stiffness of the surface layer is considerably lower than that of the bulk. These networks are synthesized by leveraging the oxygen inhibition mechanism, and we establish a power-law criterion governing the transition from a viscoelastic adhesive network to a hyperelastic adhesive network. Second, we design *homogeneous* polymer networks containing long dangling chains and a sufficient amount of good solvents. The good solvent molecules screen interchain interactions to enable hyperelasticity, while the long dangling chains can disentangle and adsorb onto diverse substrates to realize strong adhesion. We fabricate such gels by controlling polymerization kinetics: the precursor is partially cured to form a gel with long, substantially disentangled dangling chains, which consequently displays both hyperelasticity and omnidirectional adhesion. These design principles are general and applicable to various types of polymer netowrks. Hyperelastic and adhesive stretchable materials hold great promise for high-cycle, fatigue-resistant soft human–machine interfaces and other advanced applications.

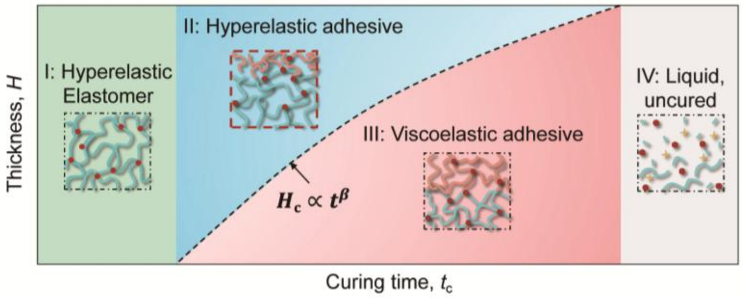

Figure 1. Polymerization phase diagram, illustrating the transition from a viscoelastic adhesive polymer network to a hyperelastic adhesive polymer network.

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Reconfigurable Nano-kirigami Surfaces: Multiscale Mechanics Modeling and Application in Optical Sensing of Environmental and Health Hazards

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Reconfigurable nano-kirigami offers a powerful route to transform planar metallic nanostructures into three-dimensional architectures with tunable geometry, mechanics, and optical functionality. In this talk, I will introduce our work on reconfigurable nano-kirigami surfaces as a platform that connects multiscale mechanics modeling with optical sensing of environmental and health hazards. Starting from suspended or substrate-supported gold nanostructures, we develop on-site nano-kirigami strategies based on programmed cutting, stress-induced buckling, twisting, and electromechanical actuation, enabling reversible and precisely controlled 2D-to-3D transformations at micro- and nanoscale dimensions.

A central theme of the talk is the mechanics behind these transformations. I will discuss how topography-guided stress equilibrium, structural instability, and electromechanical coupling can be used to predict and design complex shape changes, and how these models provide a framework for engineering optical responses across visible and near-infrared wavelengths. These reconfigurable geometries give rise to strong modulation of plasmonic behavior, including broadband and resonant optical responses, as well as tunable optical chirality that is absent in the original planar precursors.

Beyond fundamental mechanics and nanophotonics, I will highlight how such surfaces can be applied to sensing problems motivated by preventive healthcare and environmental monitoring. In particular, I will outline the concept of KIRISENSE, a kirigami-based sensing platform that integrates particle capture, surface plasmon resonance readout, and reconfigurable optical signatures for rapid, label-free, and potentially multiplex detection of airborne and surface-bound hazards. By unifying structural transformation, optical functionality, and sensing, this work points toward a new class of adaptive nano-engineered surfaces for scalable screening technologies in health and environmental applications.

Acknowledgements
The author wishes to acknowledge the financial support from Presidential Young Scholars Scheme of The Hong Kong Polytechnic University.

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An LSTM-FEA Integrated Approach to Predict Curing-Induced Deformation in Woven Thermoset Composite

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The prepreg compression moulding (PCM) process for manufacturing of complex woven composite parts involves a preforming stage that inherently induces spatially varying yarn orientations, resulting in location-dependent material properties during the subsequent curing. Consequently, prediction of curing-induced deformation demands multiscale simulation capable of capturing the complex interplay among local yarn orientations, viscoelastic resin behaviour and global structural response. However, traditional FE^2 approaches are usually computationally intractable for large and non-uniform woven CFRP structures.

To address this computation bottleneck, this study developed an integrated Long Short-Term Memory (LSTM) – Finite Element Analysis (FEA) framework. An LSTM network is first trained on a high-fidelity virtual dataset, generated from mesoscale FEA for Representative Volume Elements (RVE) across a wide range of conditions, including yarn angles, degrees of cure, temperatures and time. Subsequently, the trained network is decomposed and deployed into the chemical-thermal-mechanical coupled FEA via user subroutines for curing modelling. Experimental validation demonstrates that this LSTM-FEA integrated modelling approach can achieve excellent prediction accuracy of above 92%. At the same time, this approach is approximated to realize computational speedup of 2~4 orders of magnitude compared to conventional FE^2 methods.

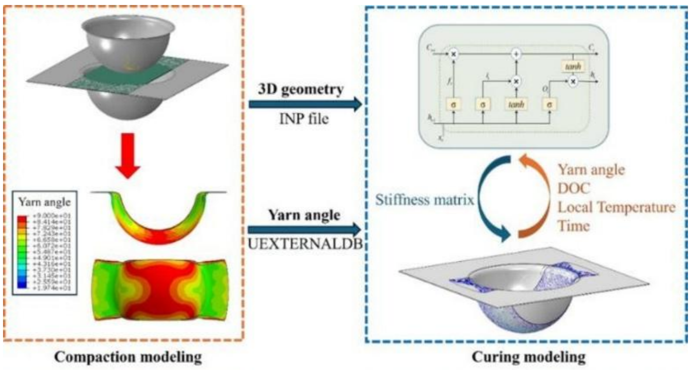

Figure 1. Flowchart of the integrated LSTM-FEA modeling approach.

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Modeling and prediction of hypersonic wall turbulence

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In this work, we will report our progress in understanding and modeling of hypersonic wall-bounded turbulence. Particular attention will be given to the scalings of mean velocity and temperature, as well as the advanced wall-modeled large-eddy simulation (WMLES) framework. We will show how the new wall models substantially improve the prediction accuracy of classical ones when coupled with the novel high-order numerical methods (e.g., the high-order TENO schemes).

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Intrinsic Interfacial Shear Characterization via Coupled Shear-Lag Model and PINN Inversion

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Interfaces between thin films and soft substrates critically determine the mechanical reliability of layered systems in flexible electronics and composites. Conventional interfacial characterization often relies on sequential coupling (SC), assuming uniform substrate strain equal to the far-field loading. This simplification neglects bidirectional film–substrate interactions and fails for compliant substrates. Moreover, most studies predefine a specific cohesive zone model (CZM), typically bilinear, though actual traction–separation behaviour is often unknown and highly nonlinear.

To address these limitations, we develop a fully coupled (FC) two-dimensional shear-lag model that rigorously incorporates bidirectional shear transfer across the interface, separating intrinsic interface properties from substrate effects. In the absence of closed-form solutions, a physics-informed neural network (PINN) inversion strategy is introduced to robustly extract intrinsic interfacial parameters from strain measurements. A piecewise-linear reconstruction scheme further allows flexible identification of CZM responses without prior specification of functional form. This unified modelling–inversion approach provides a scalable methodology for intrinsic interfacial shear characterization, broadly applicable to thin-film electronics, nanocomposites, and other hybrid material systems.

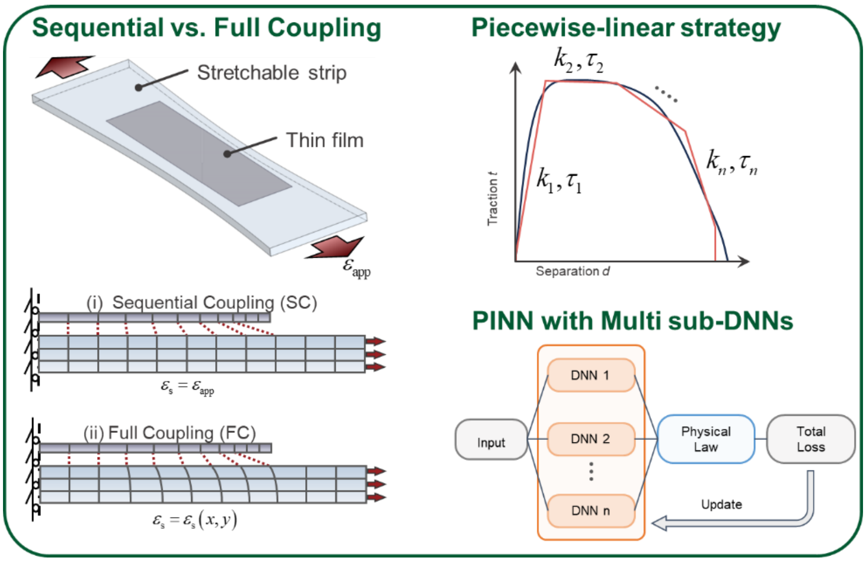

Figure 1. Conceptual illustration of the fully coupled shear-lag framework, including sequential vs. full coupling, piecewise-linear CZM reconstruction, and PINN-based inversion strategy.

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Long-term Adhesion Durability Revealed through a Rheological Paradigm

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The question of how long an object can adhere to a surface has intrigued scientists for centuries. Traditional studies focus on rapid crack-propagation detachment and account only for short-term adhesion governed by interfacial-viscoelastic dissipation, failing to explain long-term phenomena like sudden detachment after prolonged adherence and to predict corresponding adhesion lifetimes. Here, we investigate the long-term adhesion through a rheological paradigm using both theory and experiment. By considering both the bulk rheology and interfacial viscoelasticity mechanisms, we show that long-term adhesion durability is governed by the competition between them. This understanding leads to accurate lifetime predictions, which we validate through experiments. Additionally, our study reveals a previously undocumented, counterintuitive phenomenon unique to long-term adhesion: the expansion of the contact area under tensile forces, in contrast to short-term adhesion in which the contact area always shrinks during detachment. This research fills a critical gap in adhesion physics.

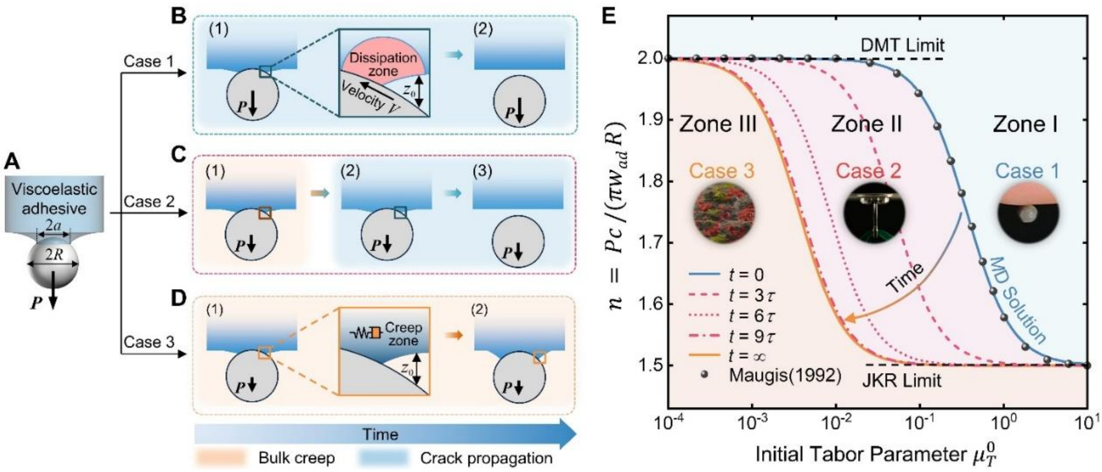

Figure 1. Analysis of the detachment of a rigid sphere from a viscoelastic adhesive substrate in three typical detachment cases.

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Regulation Mechanisms of Deformation Pathways in Multistable Metamaterials

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Multistable mechanical metamaterials have emerged as a promising class of architected materials for applications in mechanical computing, physical intelligence, and soft robotics, owing to their highly programmable deformation behaviors. Despite this potential, the underlying mechanisms governing the interactions among multistable units, the dynamic evolution of collective responses, and the precise regulation of complex deformation pathways remain insufficiently understood, thereby limiting their broader implementation in intelligent materials and structures. In this talk, I will present our recent progress in elucidating the regulatory mechanisms of deformation pathways in multistable metamaterials. In particular, I will show how complex deformation sequences can be programmed through tailored interactions among constituent units, and how avalanche-like transitions under quasi-static loading can be effectively controlled by engineering the internal dynamic characteristics of the system. Building on these mechanistic insights and control strategies, we further explore a range of intelligent applications, including mechanical bit counters, locking memory in metamaterials, and metamaterial systems with multiperiodic responses and mechanical computing capabilities.

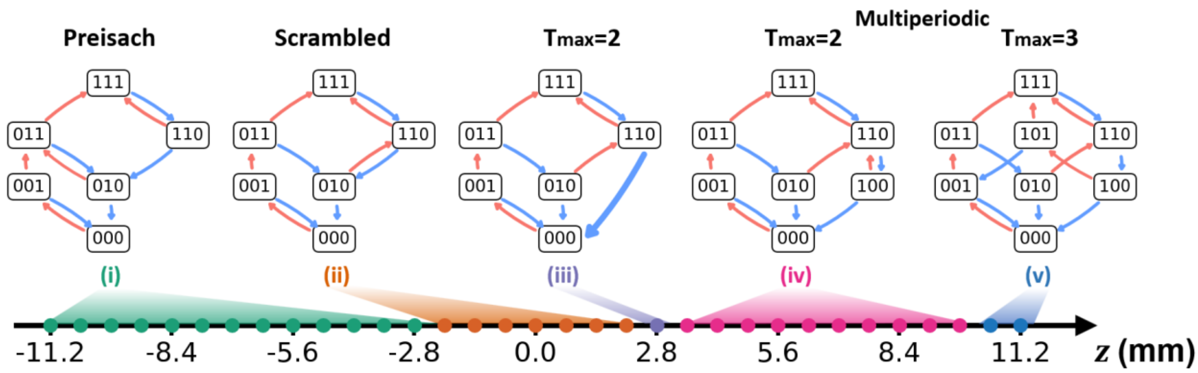

Figure 1. Rich deformation pathways in a 3-bit multistable metamaterial

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AI-driven autonomous navigation of miniature medical devices

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The clinical translation of miniature medical devices (MMDs) for minimally invasive surgery faces major challenges in real-time X-ray guidance, including poor image quality and difficult spatial control. Manual operation is labor-intensive and error-prone, while deep-learning automation is hindered by the scarcity of annotated X-ray datasets due to costly acquisition and privacy constraints. Here we present MicroSyn-X, a framework that generates high-fidelity, pixel-accurate, auto-labelled, domain-randomized synthetic X-ray images to train vision models without manual data curation. Integrated into a teleoperated robotic system, MicroSyn-X enables real-time localization and navigation of magnetic soft and liquid MMDs in both ex vivo and dynamic in vivo environments, showing robustness under low contrast, high noise, and occlusion. We release the X-ray MMD dataset open-source to support benchmarking. This work overcomes data scarcity and enables real-time robotic navigation, advancing MMD-assisted minimally invasive surgery toward next-generation precision interventions.

Ultra Strong and Tough 2D Polymer Grown by Chemical-Vapor-Deposition for Microelectronics

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Two-dimensional polymers (2DPs) with tunable porous architectures provide a promising platform for ultralow-k dielectrics in next-generation microelectronics. While conventional porous dielectrics often suffer from degraded mechanical properties, 2DPs uniquely combine low density with strong in-plane covalent bonding and interlayer interactions, enabling improved mechanical robustness. Here, we report a fluorine-rich 2DP (2DP-F) synthesized via low-temperature chemical vapor deposition (CVD). The resulting films exhibit conformal growth on arbitrary substrates, an ultralow dielectric constant (~1.8), and a relatively high Young's modulus (~18 GPa), demonstrating an effective decoupling between dielectric permittivity and mechanical stiffness. This behavior highlights the advantage of the 2DP framework in overcoming the typical porosity–mechanical trade-off. We further integrate 2DP-F as an interlayer dielectric in MoS_2 field-effect transistors, where its mechanically stable and inert interface reduces interfacial scattering and enhances device performance. In addition, hybrid 2DP–oxide structures prepared via vapor-phase metal-assisted growth below 200 °C enable tunable dielectric properties while maintaining structural integrity. These results establish 2DPs as mechanically resilient dielectrics for advanced electronic applications.

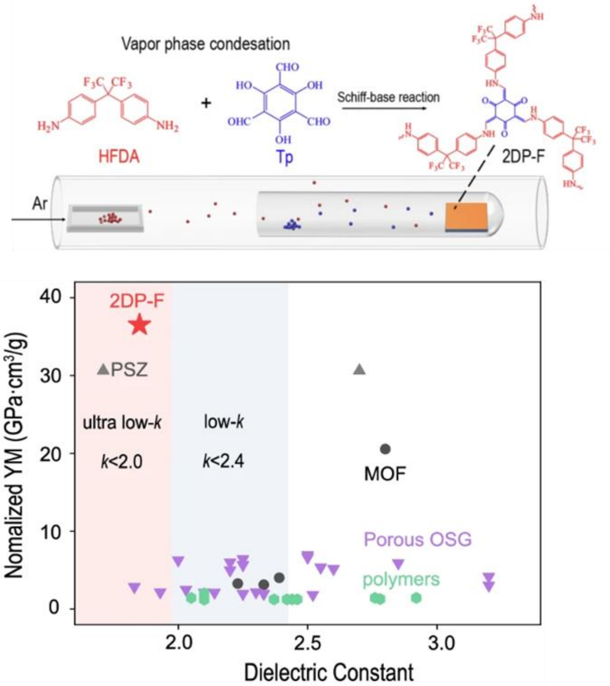

Figure 1. Schematical illustration of the growth process of 2DP (top) and its performance Comparisons of many low-k dielectric materials (bottom).

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Sensation by Design: Tailoring Friction for Next-Gen Human-Machine Synergy

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Over the last several decades, human-machine interactions have been limited to vision and audio channels. The introduction of haptics technologies has enabled users to receive mechanical feedbacks in the form of virtual touch. While the rapidly advancing haptics technologies in wearable devices and surface haptic devices have enabled many exciting applications in virtual reality (VR), augmented reality (AR), telecommunication, and teleoperation, they still suffer from issues in bulkiness, comfortability, and consistency. The solutions to these issues lie in the fundamental understanding of the multi-physics interactions in the human-machine interface, which include contact deformation, capillary formation, electric field, heat transfer, material non-linearity, and their complicated coupling effects. In this talk, Prof. Ma will discuss models on the multi-physics interactions in human-machine interface, with a special emphasis on modeling the finger friction variation on textured surfaces to design tactile sensations. This talk will also include how the multi-physics models have been applied in developing new wearable sensors, actuators, and surface haptics devices. The discussed models lay the foundation to develop haptics artificial materials (metamaterials) that can deliver any desired haptics performances for the next generation of human-machine mechanical interfaces and Metaverse.

Versatile Robotic Adhesive Skin Utilizing Shape Memory Polymers

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Electronic skins (E-skins) endow robots with sensory functions but often lack the multifunctionality of natural skin, such as switchable adhesion. Current smart adhesives based on elastomers have limited adhesion tunability, which hinders their effective use for both carrying heavy loads and performing dexterous manipulations. Here, we report a versatile, one-size-fits-all robotic adhesive skin using shape memory polymers (SMPs) with tunable rubber-to-glass phase transitions. The adhesion strength of our adhesive skin can be changed from minimal (~ 1 kPa) for sensing and handling ultra-lightweight objects, to ultra-strong (>1 MPa) for picking up and lifting heavy objects. Our versatile adhesive skin is expected to significantly enhance the ability of intelligent robots to interact with their environment.

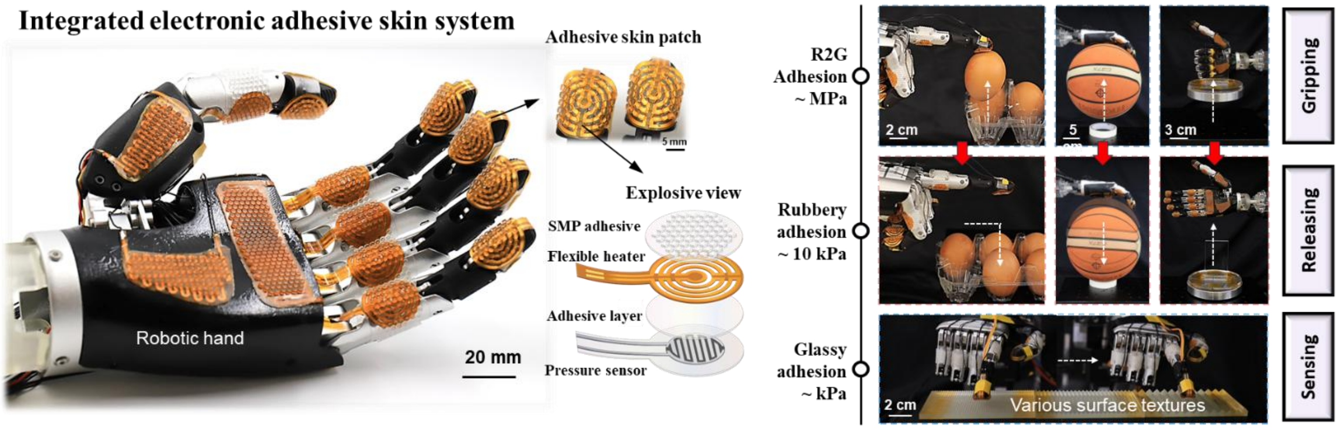

Figure 1. Versatile SMP adhesive skin enhances robotic interactions with the environment.

Acknowledgements

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Changhong Linghu[1,†], Yangchengyi Liu[1,2,†], Xudong Yang[1,†], Zhou Chen[3,†], Jin Feng[4], Yiyuan Zhang[5], Yan Li[1], Zhao Zhao[6], Young-Jae Seo[1], Junwei Li[1], Haoyu Jiang[1], Jiangtao Su[7], Yin Fang[8], Yuhang Li[9], Xiufeng Wang[2,*], Yifan Wang[1,*], Huajian Gao[10*], K. Jimmy Hsia[1,8,*]. Versatile Adhesive Skin Enhances Robotic Interactions with the Environment. *Science Advances*, 2025.

Applications of Generative Models

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Computational Fluid Dynamics (CFD) plays a vital role in modern science and engineering. As a fundamental tool for high-fidelity simulation of physical fluid fields, it is essential for analyzing complex flow phenomena and underpins design processes in fields such as aerospace [1, 2], automotive engineering [3], and energy systems [4]. While traditional CFD approaches such as the Finite Volume Method (FVM) and Finite Difference Method (FDM) provide high-fidelity solutions, their significant computational expense poses a major barrier to real-time control and design optimization. Consider a typical optimization task: it may involve thousands of CFD evaluations, each demanding hours of computational time [5]. In response to these limitations, data-driven approaches have recently emerged as a promising alternative. Generative models have gained significant traction across various research domains due to their exceptional ability to learn and replicate complex, high-dimensional data distributions. Their success in fields such as computer vision and natural language processing has sparked growing interest in adapting these techniques for scientific computing applications. The present study investigates the potential of generative models—along with their improved and task-specific variants—for the predictive modeling of critical physical fields. Specifically, this work focuses on forecasting temperature fields and flow fields, two fundamental quantities that govern a wide range of thermal and fluid systems.

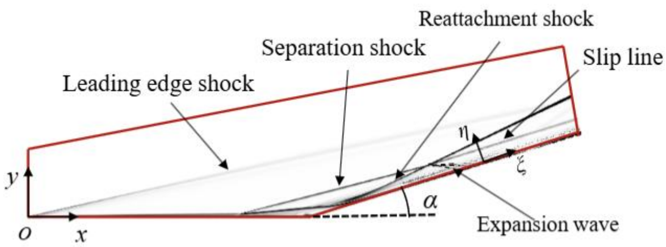

Figure 1. The hypersonic flow structure over a compression ramp with computational domain in red lines.

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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
9:00 – 12:05	Opening Addresses and 4 Distinguished Lectures	Y302
12:05 – 14:00	Lunch	Block Y Outlet
14:00 – 17:30	12 parallel sessions	Y301~Y304, Y306 & TU101
17:30 – 17:45	Closing Ceremony and Award Presentation	Y302
17:45 – 18:15	HKSTAM Annual General Meeting	Y302
18:30	Banquet	Ju Yin House Seafood Restaurant (聚賢樓), 4/F, Communal Building