WEI LI

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EDUCATION

Ph.D., Tsinghua University, School of Vehicle and Mobility, China *Sep 2014 - Jul 2019*

- Thesis: *Study on lithium-ion battery deformation and failure based on detailed modeling*
- One-year visiting study at MIT during 2017-2018

B.E., Hunan University, College of Mechanical and Vehicle Engineering, China *Sep 2010 - Jul 2014*

- Thesis: *Development of a full vehicle crash test database and feature analysis of crash pulse* (Best Bachelor's Thesis Award)
- National Fellowship (Ranked #1 in College of Mech. and Veh. Engineering)

RESEARCH INTERESTS

My research focuses on developing ***scientific machine learning*** techniques to model and simulate ***electro-chemo-mechanical systems***. Specifically, I am interested in two areas:

- **Intelligent physics-data integration**: I aim to overcome the *curse of dimensionality* by developing physics-informed neural networks that can integrate physical constraints and laws into the learning process. My goal is to create new tools that can model and simulate complex electro-chemo-mechanical systems with high accuracy and efficiency.
- **Highly-coupled multiphysics system modeling**: I specialize in using ***deep operator learning*** to improve the accuracy and speed of multiphysics simulations. By developing novel deep learning techniques, I aim to enable *fast identification* of coupled systems, which can be applied to a wide range of applications, from energy systems to biomedicine.

Overall, my research interests lie at the intersection of machine learning, physics, and engineering, and I strive to advance the field of scientific machine learning and provide new tools for modeling and simulating complex electro-chemo-mechanical systems.

RESEARCH EXPERIENCE

Associate Research Scientist— Mech. & Ind. Eng., Northeastern University, US *Jan 2023 — Present*
Supervisor: Juner Zhu

- **Develop physics-informed neural networks for complex multi-physics battery systems**
- **Investigate pressure effect and lithium penetration mechanisms of Lithium-metal solid-state batteries**

Postdoctoral Associate— Chemical Engineering, MIT, US *Oct 2022 — Jan 2023*
Supervisor: Martin Z. Bazant

- **Phase-field deep operator neural network for electrochemical systems**
  - **Phase-Field Deep Operator Neural Network (DeepONet)**: Developed a physics-informed DeepONet with a free energy-based loss function that solves phase-field equations (Allen-Cahn and Cahn-Hilliard equations)

Postdoctoral Associate— Mechanical Engineering, MIT, US *Jan 2020 — Oct 2022*
Supervisor: Tomasz Wierzbicki

- **Physics-informed machine learning applications in battery modeling**

- **Physics-informed machine learning (PINN)**: Developed and compared the PDE-based and energy-based PINN frameworks for solving the plate theory
- **Inverse learning**: Integrated both experimental data and partially known physics into a PINN framework to inversely learn the fluid flow parameters for the fluid-solid interaction problem

- **New CAE tools for batteries, (MIT Industrial Battery Consortium)**
  - **Computational mechanics**: Developed high-efficiency battery models and implemented large deformation plasticity and fracture theories into FE codes
  - **Next-generation batteries**: Developed models for Li-metal batteries and all-solid-state batteries

Research Assistant — School of Vehicle and Mobility, Tsinghua University, China *Sep 2014 - Jul 2019*
Supervisor: Qing Zhou and Yong Xia

- **Data-driven safety envelope of lithium-ion batteries for electric vehicles**
  Aug 2018 — Mar 2019
  - **Dig data**: generated a big database for the impact safety of batteries based on high-fidelity FE models
  - **Data-driven safety envelop**: Generated safety envelops utilizing machine learning algorithms
- **Detailed modeling of lithium-ion batteries**
  Oct 2017 — Aug 2018
  - **Large-deformation plasticity**: Characterized the mechanical properties of electrode coatings and developed both continuum and discrete particle models
  - **Structural mechanics**: Developed a detailed multi-layer FE model that accurately predicts the large deformation and fracture behaviors of batteries
- **Mechanical-electrical-thermal responses of lithium-ion batteries**
  Mar 2017 — Oct 2017
  - **Multi-physics analysis**: Experimentally compared the electrical, thermal, and mechanical responses under mechanical loadings for the pouch, prismatic, and cylindrical cells
  - **Failure mechanism analysis**: Observed and summarized the fracture patterns and the correlations between fracture modes and the thermal-electrical behaviors after short circuit
- **State-of-charge dependence of mechanical response of lithium-ion batteries**
  Aug 2016 — Mar 2017
  - **Experimental design**: Designed different experimental setups to measure the contained reaction force and free expansion of batteries
  - **Mechanism analysis**: Analyzed and experimentally confirmed that the SOC-effect is due to the internal stress
- **Fracture mode transition of lap-shear spot-welded joints under dynamic loading**
  Jan 2015 — Jul 2016
  - **Mechanics of materials**: Characterized the large deformation plasticity and fracture behavior and the rate-dependence for the base metals and SW joint
  - **Experimental techniques**: In-house designed light-weight force sensor in dynamic tests; miniature specimens to test mechanical properties of SW joint
  - **Finite element modeling**: Developed detailed FE model for the spot-welded joints to reproduce the fracture transition under dynamic loading

TEACHING EXPERIENCE

Kaufman Teaching Certificate Program, MIT *Sep 2021 - Dec 2021*

- Practice-based workshop series for designing and teaching a course

- Developed a course for Finite Element Method and delivered two microteaching sessions

Teaching assistant of *Fundamentals of Vehicle Crash Safety* course, Tsinghua University *2015 Fall & 2016 Fall*

- Lectures given in English
- Support in-class activities, exams, and grading

PUBLICATIONS

First-author Journal Publications (= Authors with equal contribution)

[1] **W. Li**, M. Z. Bazant, and J. Zhu. Phase-Field DeepONet: Physics-informed deep operator neural network for fast simulations of pattern formation governed by gradient flows of free-energy functionals. **Comp. Meth. in App. Mech. and Eng**, 416: 116299, 2023.

[2] **W. Li**, B Xing, et al. Damage of prismatic lithium-ion cells subject to bending: Test, model, and detection. **EcoMat**, 4(6):e12257, 2022.

[3] **R. Li**= **W. Li**= , et al. Effect of external pressure and internal stress on battery performance and lifespan, **Energy Storage Materials**, (52) 395-429, 2022.

[4] **W. Li**, J. Zhu, & M. Z. Bazant. A Physics-Guided Neural Network Framework for Elastic Plates: Comparison of Governing Equations-Based and Energy-Based Approaches. **Comp. Meth. in App. Mech. and Eng**, 383: 113933, 2021.

[5] **W. Li** , & J. Zhu. A large deformation and fracture model of lithium-ion battery cells treated as a homogenized medium. **Journal of The Electrochemical Society**, 167(12), 120504, 2020.

[6] **W. Li**= , J. Zhu=, Y. Xia, et al. Data-driven safety envelope of lithium-ion batteries for electric vehicles, **Joule**, 2019.

[7] J. Zhu=, **W. Li** =, et al. Deformation and failure of lithium-ion batteries treated as a discrete layered structure. **International Journal of Plasticity**, 2019.

[8] **W. Li** , Y. Xia, et al. Comparative study of mechanical-electrical-thermal responses of pouch, cylindrical, and prismatic lithium-ion cells under mechanical abuse. **Science China Technological Sciences**, 2018, 61 (10), 1472-1482.

[9] **W. Li** , Y. Xia, et al. State-of-charge dependence of mechanical response of lithium-ion batteries: A result of internal stress. **Journal of The Electrochemical Society**, 2018, 165 (7), A1537-A1546.

[10] J. Zhu=, **W. Li**= , Y. Xia, and E. Sahraei, Testing and modeling the mechanical properties of the granular materials of graphite anode, **Journal of The Electrochemical Society**, 165 (5), A1160, 2018.

[11] **W. Li** , J. Zhu, et al. Testing and modeling the effect of strain-rate on plastic anisotropy for a traditional High Strength Steel. ASME 2015 **International Mechanical Engineering Congress and Exposition**, 2015

Co-authored Journal Publications

[1] D. Cao, K. Zhang, **W. Li** , et al. Nondestructively Visualizing and Understanding the Mechano-Electro-chemical Origins of “Soft Short” and “Creeping” in All-Solid-State Batteries. **Advanced Functional Materials**. 2307998, 2023.

[2] L. Zhao, **W. Li** , C. Wu, et al. Taming Metal–Solid Electrolyte Interface Instability via Metal Strain Hardening. **Advanced Energy Materials**. 13(34), 2300679, 2023.

[3] Y. Wang, J. Sun, **W. Li** , Z. Lu, Y. Liu. CENN: Conservative energy method based on neural networks with subdomains for solving variational problems involving heterogeneous and complex geometries. **Comp. Meth. in App. Mech. and Eng**. 400:115491, 2022.

[4] J. Zhu, I. Mathews, D. Ren, **W. Li** , D. Cogswell, B. Xing, T. Sedlatschek, N. Kantareddy, M. Yi, T. Gao, Y. Xia, Q. Zhou, T. Wierzbicki, M. Z. Bazant,, End-of-life or second-life options for retired electric vehicle batteries, **Cell Reports Physical Science**, 2 (8), 100537, 2021.

[5] H. Xu, J. Zhu, **W. Li** , M. Z. Bazant. et al., Guiding the Design of Heterogeneous Electrode Microstructures for Li-Ion Batteries: Microscopic Imaging, Predictive Modeling, and Machine Learning, **Advanced Energy Materials**, 11 (19), 2003908, 2021.

[6] T. Wierzbicki, **W. Li** , Y. Liu, and J. Zhu, Effect of receptors on the resonant and transient harmonic vibrations of Coronavirus, **Journal of the Mechanics and Physics of Solids**, 150, 104369, 2021.

[7] T. Sedlatschek, J. Lian, **W. Li** , et al., Large-deformation plasticity and fracture behavior of pure lithium under various stress states, Acta Materialia, 208, 116730, 2021.

[8] D. P. Finegan, J. Zhu, X. Feng, **W. Li** , et al., The application of data-driven methods and physics-based learning for improving battery safety, **Joule**, 5 (2), 316–329, 2021.

[9] J. Zhu, M. M. Koch, J. Lian, **W. Li** , and T. Wierzbicki, Mechanical deformation of lithium-ion pouch cells under in-plane loads—Part I: experimental investigation, **Journal of The Electrochemical Society**, 167 (9), 090533, 2020.

[10] Z. Pan, J. Zhu, H. Xu, T. Sedlatschek, X. Zhang, **W. Li** , T. Gao, Y. Xia, T. Wierzbicki, Microstructural deformation patterns of a highly orthotropic polypropylene separator of lithium-ion batteries: Mechanism, model, and theory, **Extreme Mechanics Letters**, 37, 100705, 2020.

[11] Z. Pan, **W. Li** , and Y. Xia, Experiments and 3D detailed modeling for a pouch battery cell under impact loading, **Journal of Energy Storage**, 27, 101016, 2020.

[12] J. Lian, M. Koch, **W. Li** , T. Wierzbicki, and J. Zhu, Mechanical deformation of Lithium-ion pouch cells under in-plane loads—Part II: Computational modeling, **Journal of The Electrochemical Society**, 167(9), 090556, 2020.

[13] J. Zhu, H. Luo, **W. Li** , T. Gao, Y. Xia, and T. Wierzbicki, Mechanism of strengthening of battery resistance under dynamic loading, **International Journal of Impact Engineering**, 131, 78–84, 2019.

[14] J. Lian, T. Wierzbicki, J. Zhu, and **W. Li** , Prediction of shear crack formation of lithium-ion batteries under rod indentation: Comparison of seven failure criteria, **Engineering Fracture Mechanics**, 217, 106520, 2019.

[15] J. Zhu, T. Wierzbicki, and **W. Li** , A review of safety-focused mechanical modeling of commercial lithium-ion batteries, **Journal of Power Sources**, 378, 153–168, 2018.

[16] Z. Qin, J. Zhu, **W. Li** , Y. Xia, and Q. Zhou, System ringing in impact test triggered by upper-and-lower yield points of materials, **International Journal of Impact Engineering**, 108, 295–302, 2017.

[17] G. Chen, **W. Li** , H. Luo, and Y. Xia, Influence of mechanical interaction between lithium-ion pouch cells in a simplified battery module under impact loading, **ASME** 58493, V014T11A029, 2017.

[18] Z. Qin, **W. Li** , J. Zhu, and Y. Xia, Experimental and numerical analysis of the system ringing in intermediate strain rate tests, **ASME**, 50633, V009T12A031, 2016.

ORAL PRESENTATIONS

Invited Talks

- Scientific Machine Learning Modeling of Batteries. **Microsoft Research Asia, AI4Science, Frontier Sharing**, 2022.
- Physics-informed neural network framework for multi-physics modeling of battery. **Engineering and Applied Science Forum (EASF)**, 2021.
- Physics-guided machine learning modeling of battery. **Automotive & Battery Safety Conference (ABSC)**, 2021
- Mechanical Failure of Lithium-Ion Batteries, **9th Annual Battery Safety Conference**, 2019.

Conference Presentation

- Phase-Field DeepONet: Physics-informed deep operator neural network for fast simulations of pattern formation governed by gradient flows of free-energy functionals, **3rd ICMAMS**, 2023
- Deep operator machine learning framework for modeling all-solid-state batteries, **3rd ICMAMS**, 2023
- Energy-Based Deep Operator Learning for Solving Battery Physics Equations, **AIAA SciTech, NASA 2040 Vision IV**, 2023
- Variational Principle Neural Network for dynamics of conservative physical systems – solving the phase-field model of dynamic fracture, **USNC/TAM** 2022.
- Damage of prismatic lithium-ion cells subject to bending: test, model, and detection, **USNC/TAM** 2022.
- Identify fluid flow parameters in porous media using physics-informed machine learning. **Mechanistic Machine Learning and Digital Twins Conference (MMLDT)**, 2021
- Mechanical Testing and Modeling of the Graphite Anode of Lithium-ion Batteries, **ASME International Mechanical Eng. Congress & Exposition**, 2019
- State-of-Charge Dependence of Mechanical Response of Lithium-ion Batteries, **ASME International Mechanical Eng. Congress & Exposition**, 2019

REFEREES

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