From Physics to Data: Machine Learning for Composite Materials and Structures

Speaker: Professor Qiang Chen, Xi'an Jiaotong University
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Abstract: The response of composite materials is strongly governed by their underlying microstructural morphology and the local constitutive behavior of the constituent phases. Homogenization theories can provide highly accurate predictions by explicitly accounting for interactions between reinforcements and the surrounding matrix while accommodating diverse constitutive laws. However, classical micromechanics models often exhibit limited predictive capabilities, whereas modern numerical approaches, particularly in multiscale settings, incur prohibitive computational and memory costs.

In this talk, I will first present recent advances by my research group in the development of deep homogenization neural network approaches for the periodic homogenization of conventional composites and nanocomposites. These developments account for thermo-mechanical coupling, surface elasticity effects, piezoelectric behavior, cylindrical orthotropy, cohesive interfaces, and finite-deformation responses in two- and three-dimensional periodic microstructures.

I will then introduce our recent work on thermodynamically consistent neural network models based on transformer architectures and temporal convolutional networks for constitutive modeling of elastoplastic and viscoelastic-viscoplastic-damage behaviors in homogeneous and heterogeneous materials and structures using sequential data. In particular, I will demonstrate the feasibility of learning the constitutive behavior of composite materials directly from stress data.

Finally, I will discuss a range of data-driven approaches for accurate and efficient concurrent multiscale modeling of composite structures.

Speaker profile:

Mr. Qiang Chen is a professor at Xi'an Jiaotong University, where he leads the Composite Materials Research Group. He received his PhD from Xi'an Jiaotong University and completed part of his doctoral studies at the University of Virginia. From 2021 to 2023, he worked as a postdoctoral researcher at the Arts et Métiers Institute of Technology. He also has industrial experience as an algorithm engineer.

Professor Qiang Chen's research focuses on composite materials and structures. He is the developer of physics-informed deep homogenization neural networks (DHN) and several other data-driven methodologies for composites with periodic microstructures. His work has also contributed to the development of in-house finite-volume and finite-element numerical codes, as well as elasticity-based theoretical approaches aimed at better understanding fundamental physics and material behaviors of composites. He has published over 60 peer-reviewed journal articles in leading journals such as CMAME, IJP, IJSS, IJMS, Composites Part A and B, and CSTE. He is the principal investigator of 5 research projects.