Learning the history-dependent material behavior of viscoelastic composites using recurrent neural operator

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Paper ID: 383
Symposium S10: Coupled problems in material mechanics
Extended Abstract

Abstract

Modelling the finite-deformation, history-dependent behaviour of heterogeneous viscoelastic composites remains a challenge due to the complex interactions across multiple scales. High-fidelity methods, such as FE2 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 techniques to transform multiscale modelling of complex materials, offering an efficient and scalable alternative to conventional approaches.

Keywords:

Machine learning Viscoelasticity Neural operator Multiscale modeling