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DEEP LEARNING AND PHASE-FIELD METHODS FOR FRACTURE, DAMAGE AND FAILURE MECHANICS

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ABSTRACT

Phase-field modelling has emerged as a powerful computational framework for simulating complex fracture processes without explicit tracking of evolving crack surfaces. Despite its versatility in capturing crack initiation, propagation, branching and coalescence, conventional phase-field approaches remain computationally demanding, particularly for three-dimensional, multiscale and fatigue-fracture problems. At the same time, rapid developments in deep learning and scientific machine learning are creating new opportunities to enhance the efficiency, scalability and predictive capability of phase-field fracture models.

This invited minisymposium focuses on recent developments at the intersection of deep learning and phase-field modelling for fracture, damage and failure mechanics. Particular attention will be given to deep neural network formulations for solving phase-field fracture problems, including deep energy methods, physics-informed neural networks (PINNs), neural operators and other physics-informed learning strategies. Contributions exploring hybrid approaches in which machine learning is integrated with conventional finite-element phase-field formulations are also particularly encouraged.

The minisymposium will address both brittle[1] and cohesive fracture and welcomes extensions to ductile fracture, fatigue, heterogeneous and composite materials, and coupled multiphysics failure. Topics of interest include deep-learning-based solution of coupled displacement–phase-field equations, data-driven identification of phase-field parameters and constitutive behaviour, surrogate and reduced-order models, neural operators for rapid fracture prediction, adaptive learning strategies, and computational acceleration of large-scale phase-field simulations.

A central objective is to examine how deep learning can overcome some of the computational limitations of conventional phase-field methods while retaining physical consistency, robustness and generalisability. Contributions addressing accuracy, convergence, interpretability, training efficiency and comparisons with established finite-element solutions and experimental observations are especially welcome.

By bringing together researchers in phase-field fracture, computational mechanics and scientific machine learning, the minisymposium aims to promote new computational paradigms for efficient and physically informed prediction of fracture, damage and

structural failure.

REFERENCES

[1] Ghaffari Motlagh Y., Jimack P.K. and de Borst, RT., *Deep learning phase-field model for brittle fractures* , International Journal for Numerical Methods in Engineering, Vol. 124(3), PP.620-638**,** 2023.