

MACHINE LEARNING-AIDED COHESIVE ZONE MODELING OF FATIGUE DELAMINATION

OVERVIEW

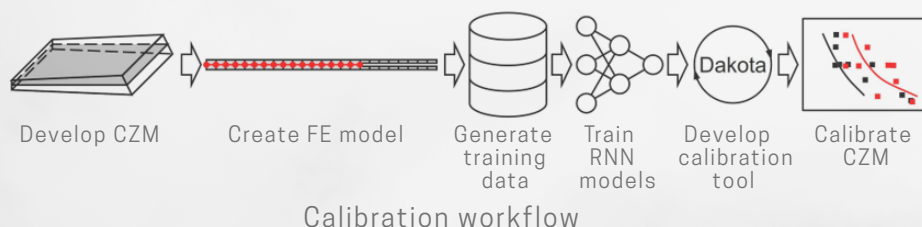
Composite laminates are widely used in aerospace, automotive, and other industries due to their superior mechanical properties and design flexibility. However, they are prone to failure by fatigue delamination under intensive cyclic loading, primarily due to insufficient reinforcement in the thickness direction. Manual fatigue life testing is often labor-intensive, time-consuming, and error-prone. Cohesive zone models (CZMs) address these challenges effectively by idealizing fracture process zones (FPZs) as separable interfaces governed by cohesive laws. This project introduces a machine learning-aided approach to CZMs, enhancing accuracy and efficiency while reducing computational and testing efforts.

Using this novel approach, we deliver accurate and efficient fatigue delamination modeling that eliminates the need for preexisting crack assumptions. By incorporating machine learning, the method drastically reduces computational time and provides customizable cohesive laws for tailoring interfacial strength and fracture modeling to specific needs.

KEY BENEFITS

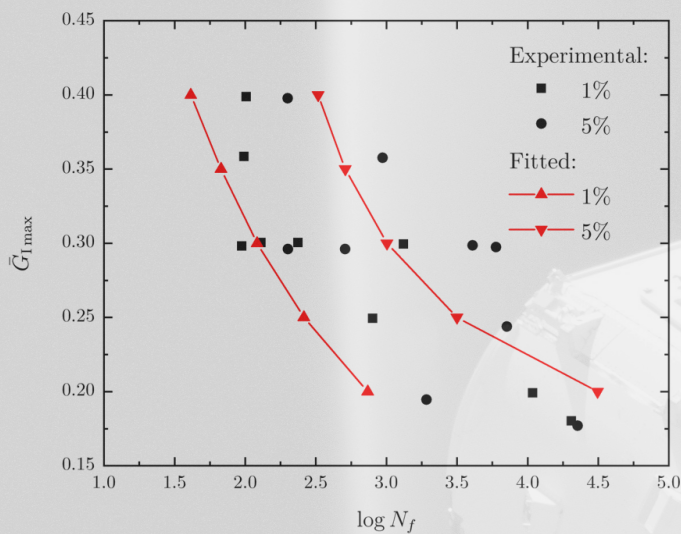
TECHNICAL APPROACH

This project introduces a machine learning-aided cohesive zone model (CZM) for fatigue delamination, utilizing a viscodamage model sensitive to maximum cyclic energy release rates. Implemented in third party tool Abaqus/Standard via UMAT, the model calibrates key parameters through experimental setups like DCB, ENF, and MMB tests. Feedforward neural networks replace costly finite element analyses and integrate into the third party open source Dakota toolkit for automated model calibration.



RESULTS

The developed framework has been validated using DCB and ENF tests on unidirectional E-glass fiber/E722 composite beams, demonstrating the CZM's capability in handling mixed-mode delamination. The model produces physically realistic traction–separation curves, reliable simulation results, and enables users to customize interfacial strength and critical energy release rate relationships.



Relationships between maximum mode I cyclic energy release rates and numbers of cycles to delamination

APPLICATIONS

This advanced CZM finds applications in modeling mixed-mode fractures in brittle materials, predicting delamination in composite structures, and simulating fiber–matrix or particle–matrix interfacial debonding. These capabilities are particularly relevant in aerospace, automotive, and other industries relying on high-performance composite materials.

FUTURE DIRECTIONS

The current CZM can be extended to incorporate additional damage accumulation laws and expanded to accommodate a broader range of applications in mixed-mode fractures and advanced composite materials. By refining and scaling the methodology, we aim to push the boundaries of composite material modeling for industry-wide adoption. Please contact us for additional information, free trial licenses, or to explore collaboration opportunities.