

A Multiscale Perspective on Fracture in Fiber-Reinforced Composites

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Brief Biographical Sketch

Dr. Harpreet Singh is an Associate Professor in the School of Mechanical Sciences at the Indian Institute of Technology Goa. He obtained his Ph.D. in Applied Mechanics from IIT Delhi. Prior to joining academia, he gained extensive industry experience working with Siemens in India and the USA, as well as at the Bhabha Atomic Research Centre. His research focuses on multiscale modeling of composite materials, particularly under extreme loading conditions, including impact, damage, and fracture. His work integrates computational mechanics with emerging approaches, such as AI/ML in solid mechanics. He has led several funded research projects and published widely in leading journals in mechanics and composite materials. Dr. Singh is also actively involved in teaching core and advanced courses in continuum mechanics, finite element methods, and composite materials, and has received multiple recognition for teaching excellence.

Abstract

Fracture in fiber-reinforced composites is governed by complex interactions between microscale inelasticity, damage evolution, and crack propagation across heterogeneous microstructures. Accurately capturing these mechanisms within a computationally efficient framework remains a significant challenge in predictive modeling. This talk presents a multiscale framework for analyzing fracture in composites by integrating reduced-order micromechanics with data-driven characterization techniques. At the core of the approach is an enhanced Transformation Field Analysis (E^2 -TFA) formulation that enables an efficient representation of microscale elastoplasticity and its role in damage initiation. The framework captures the evolution of localized deformation and provides insight into the onset of fracture under complex loading conditions. To further understand the progression from damage initiation to fracture, a data-driven methodology is introduced to systematically characterize failure morphologies. Using clustering techniques, distinct patterns of damage localization and crack evolution are identified from high-fidelity simulation data. This enables classification of fracture modes and reveals underlying mechanisms governing crack paths and failure patterns in heterogeneous composites.