Title:

Predictive modeling of ductile damage in composite materials for high-pressure hydrogen storage using finite element and Machine Learning approaches

Abstract :

This work investigates the degradation mechanics of composite materials under high-pressure conditions, targeting applications in hydrogen storage. By integrating finite element modeling (FEM) with machine learning (ML) techniques, we propose a comprehensive approach to predict and classify ductile damage evolution within fiber-reinforced polymer composites. Representative volume elements (RVEs) are modeled to simulate stress and strain distributions under varied tensile, compressive, and shear loads, capturing the nuanced interactions between fiber and matrix materials. Key parameters such as fiber volume fraction, matrix composition, and the anisotropic behavior of the fibers were analyzed to assess their impact on degradation patterns. The hybrid model employs both k-nearest neighbors (k-NN) with dynamic time warping and a bidirectional long short-term memory (Bi-LSTM) network to forecast strain degradation as a temporal dataset, reflecting both elastic and plastic material responses. Results indicate that composite performance under high-pressure conditions can be optimized through targeted processing of matrix and fiber configurations, revealing valuable insights into the predictive modeling of material degradation. This methodology advances the development of robust composite structures and presents a pathway to enhanced safety and durability in hydrogen storage applications.