Machine Learning Prediction of Compressive Damage and Energy Absorption in Carbon Fiber-Reinforced Polymer Tubular Structures

Authors : Milad Abbasi

Abstract : Carbon fiber-reinforced polymer (CFRP) composite structures are increasingly being utilized in the automotive industry due to their lightweight and specific energy absorption capabilities. Although it is impossible to predict composite mechanical properties directly using theoretical methods, various research has been conducted so far in the literature for accurate simulation of CFRP structures' energy-absorbing behavior. In this research, axial compression experiments were carried out on hand lay-up unidirectional CFRP composite tubes. The fabrication method allowed the authors to extract the material properties of the CFRPs using ASTM D3039, D3410, and D3518 standards. A neural network machine learning algorithm was then utilized to build a robust prediction model to forecast the axial compressive properties of CFRP tubes while reducing high-cost experimental efforts. The predicted results have been compared with the experimental outcomes in terms of load-carrying capacity and energy absorption capability. The results showed high accuracy and precision in the prediction of the energy-absorption capacity of the CFRP tubes. This research also demonstrates the effectiveness and challenges of machine learning techniques in the robust simulation of composites' energy-absorption behavior. Interestingly, the proposed method considerably condensed numerical and experimental efforts in the simulation and calibration of CFRP composite tubes subjected to compressive loading.

Keywords : CFRP composite tubes, energy absorption, crushing behavior, machine learning, neural network
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