ICCES, 2025, vol.34, no.1

Tech Science Press

DOI: 10.32604/icces.2025.012395

PROCEEDINGS

Spatio-Temporal Prediction of Curing-Induced Deformation for Composite Structures Using a Hybrid CNN-LSTM and Finite Element Approach

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ABSTRACT

Coordinated control of structural accuracy and mechanical properties is the key to composites manufacturing and the prerequisite for aerospace applications. In particular, accurate and efficient prediction of curing-induced deformation (CID) is of vital importance for fiber reinforced polymer composites quality control. In this study, we explored a novel spatio-temporal prediction model, which incorporates the finite element method with a deep learning framework to efficiently forecast the curing-induced deformation evolution of composite structures. Herein, we developed an integrated convolutional neural network (CNN) and long short-term memory (LSTM) network approach to capture both the space-distributed and time-resolved deformation from multi-parameter time series with spatial distribution. The numerical method combined with the bridging model was established to simulate deformation evolution and generate a comprehensive database. In contrast to conventional rapid prediction models that can only calculate the deformation after curing, the primary focus in developing this strategy lies in characterizing the spatio-temporal variations of warpage. The validations of composite laminates and sandwich structures with different stacking sequences demonstrate the model's accuracy in predicting curing-induced deformation of composites. The proposed framework provides a promising approach to predict curing-induced warpage evolution for optimizing the process and precisely controlling part quality.

KEYWORDS

Polymer-matrix composites (PMCs); curing; deep learning; deformation; finite element analysis (FEA); spatio-temporal prediction

Funding Statement: The authors acknowledge the financial support of the National Natural Science Foundation of China (Grant No.12472139; 12202312; 12402169); the National Key Research and Development Program of China (Grant No. 2022YFB4602000); and the Natural Science Foundation of Shanghai (Grant No. 24ZR1471700).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.