ICCES, 2025, vol.33, no.2

Tech Science Press

DOI: 10.32604/icces.2025.011507

PROCEEDINGS

Physical Field Prediction of Fiber-Reinforced Composite Based on Improved Convolutional Neural Network and Generative Representative Volume Element Model

Qiuze Yao, Zhensheng Wu and Xiang Peng*

College of Mechanical Engineering, Zhejiang University of Technology, Hangzhou, 310015, China

*Corresponding Author: Xiang Peng. Email: pengxiang@zjut.edu.cn

ABSTRACT

Fiber-reinforced composites are widely applied in various fields due to their high strength and modulus, and analyzing their physical field is crucial for improving material performance and structural design. However, traditional analysis methods, such as finite element analysis (FEM) and numerical computation are still limited by computational efficiency and accuracy when applied to microstructures. To address this challenge, convolutional neural network (CNN) approaches are being developed to quickly and accurately predict the physical fields in fiber-reinforced composites. Under static loading, the U-Net framework is developed with an adaptive two-stage training approach to address the generalization issue of representative volume element (RVE) of fiber composites with diverse fiber volume fractions. Under dynamic loading, the 3D TransU-Net framework is constructed by incorporating transformer mechanism and three-dimensional model, which can accurately predict the multi-component physical fields for each step along specific load path. Subsequently, a transfer learning is employed, using only a small number of samples, to extend the model's generalization ability across different load paths. To further optimize the loss function, it is necessary to integrate physical information of material property and loading conditions, aiming to imitate more realistic condition. For the choice of performance metrics, the relative error and coefficient of determination are selected to validate the model's fitting degree and accuracy of stress distribution predictions.

KEYWORDS

Fiber-reinforced composites; physical stress; convolutional neural network; fiber volume fraction; load path; physical information

Funding Statement: This work was supported by the National Natural Science Foundation of China [grant numbers 51875525], the Fundamental Research Funds for the Provincial Universities of Zhejiang [RF-B2024004].

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