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A DEEP LEARNING APPROACH FOR STRESS TENSOR FIELD PREDICTION AND MULTISCALE MODELING OF FIBER-REINFORCED COMPOSITE MATERIALS

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The macroscale behavior of materials depends on the microstructural heterogeneity. Furthermore, the microstructural morphology is affected by the loading at the macroscale. This coupling between the local structure and the macroscopic property are often modeled using multiscale approaches such as the finite element method (FEM). However, multiscale FEM requires many calculations at the local scale which are often infeasible to tract. Here, we report a significantly faster data-driven machine learning based approach in multiscale materials modeling. In this work, we first develop a deep learning model to predict stress tensor field at the local level in a fiber-reinforced composite material. A mapping between the fiber reinforced composite microstructure image and the corresponding 2D stress tensor field is achieved by using a convolutional neural network (CNN), specifically a U-Net architecture. The deep learning model is trained using a set of input and output image data obtained from running the FEM model for a series of random microstructures under uniaxial tension and shear. We also report 4-fold increase in the training sample size by performing data augmentation taking advantage of the physics of the problem. Further, using the principle of superposition, we generalize the deep learning model to provide stress tensor field corresponding to any arbitrary strain loading. Then we use this model in a multiscale simulation framework with excellent accuracy in both homogenization of elastic material properties and localization of stress tensor field. The numerical example studied demonstrates the role of stochastic microscopic features (spatial distribution of fibers in the matrix) in the overall design of macroscale L-shaped plate (critical stress etc.). Our approach shows tremendous potential in the efficient multiscale analysis of materials.

REFERENCES

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