

Microstructure reconstruction using a transfer learning approach and structure-property studies with applications to porous materials

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Abstract:

Deep learning approaches, in particular convolutional neural networks, are particularly well-suited to process microstructures image data and study structure-property links. An additional loss function based on short-range-correlation (SRC) model is introduced in the framework of transfer-learning based optimization approach to model random media. We integrate information about the microstructural descriptors such as n-point correlation functions, lineal path function etc. within a deep neural network framework, for example, by including them in the overall objective function. This helps us achieve significant computational efficiency in reconstructing microstructures that retain the critically important physical properties of the original microstructure. This method for reconstructing random multiphase materials from 2D images is further extended for reconstructing 3D microstructures. Numerical examples for the reconstruction of 2D and 3D bi-phase porous ceramic material demonstrate the efficiency of the proposed methodology. We further analyze the algorithm's capacity to capture the variability of various material properties with respect to those of the target microstructure by performing a detailed finite element analysis (FEA) of the reconstructed porous microstructures to calculate effective elastic modulus, thermal conductivity, and hydraulic conductivity.