Mechanical Engineering Doctoral Defense

Material failure simulation with random microstructure using lattice particle method and neural network

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Abstract

Extensive efforts have been devoted to understanding material failure in the last several decades. A suitable numerical method and specific failure criteria are required for failure simulation. The finite element method is the most widely used approach for material mechanical modelling as a continuous method. Since it is based on partial differential equations, it may be hard to solve problems involving spatial discontinuities, such as fracture and material interface. Due to their intrinsic characteristics of integro-differential governing equations, discontinuous approaches are more suitable for problems involving spatial discontinuities, such as lattice spring method, discrete element method, and peridynamics. A recently proposed lattice particle method belongs to the discontinuous method group, and has no restriction of Poisson's ratio, which is very common in discontinuous methods. In this study, the lattice particle method is adopted to study failure problems. In addition of numerical method, failure criterion is essential for failure simulations. In this study, multiaxial fatigue failure is investigated and then applied to the adopted method. Another issue of failure simulation is that the simulation process is time-consuming. To reduce computational cost, the lattice particle method can be partly replaced by neural network model. First, the development of a nonlocal maximum distortion energy criterion in the framework of a Lattice Particle Model is presented for modeling of elastoplastic materials. The basic idea is to decompose the energy of a discrete material point into dilatational and distortional components, and plastic yielding of bonds associated with this material point is assumed to occur only when the distortional component reaches a critical value. Then, two multiaxial fatigue models are proposed for random loading and biaxial tension-tension loading, respectively. Following this, fatigue cracking in homogeneous and composite materials is studied using the lattice particle method and the proposed multiaxial fatigue model. Bi-phase material fatigue crack simulation is performed. Next, an integration of an efficient deep learning model and the lattice particle method is presented to predict fracture pattern for arbitrary microstructure and loading conditions. With this integration, computational accuracy and efficiency are both considered. Finally, some conclusion and discussion based on this study are drawn.

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