Meso-scale Peridynamic Simulation of Crack Deflections in Heterogeneous Material under Thermomechanical Environment

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Abstract

Peridynamic approach with a new non-uniform discretization is applied to investigate crack propagation/deflection in heterogeneous material such as fiber-reinforced ceramic matrix composite. At the presence of a weak interphase between the fibers and matrix, matrix cracks propagate through the dense matrix and are deflected around the fiber through the interphase region. Deflection of matrix cracks at the interphase depends on the relative strengths of constituent materials, microstructures of interphase and residual stresses. By selecting optimized strength ratio between matrix and interphase, it is possible to double the load carrying capacity of a SiC/SiC CMC with BN interphase. In many cases, it is observed that the debonding or cracking in the interphase occurs at some distance in front of the primary crack; and these cracks arrest or retards the growth of the primary crack. However, conventional numerical method does not allow for cracks' interactions, a major limitation caused by the singularities near crack tips. The present work focuses on simulating crack deflections based on peridynamics with a new non-uniform discretization in a 3-D meso-scale model. An initial crack is inserted to the top edge. The horizon size is adaptive to local mesh density, $\delta_{(i)} = 3\Delta_{(i)}$. Tensile displacement constraints are applied to the left and right edges in horizontal direction. The prediction shows that the initial crack propagates from the pre-cracked edge towards the other side. Due to the weak interphase between matrix and fiber, the crack deflects to the closest interphase and propagates along the interphase regions. With load increase, crack migrates to the nearby interphases, thus, it forms complex damage pattern and highly arbitrary crack paths. These observations have good agreement to the experimental results, thus, verify the capability of the present PD approach.

Keywords:

Peridynamics; Mesoscale; Crack Deflection; Heterogeneous Material