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Simulation of the microlevel damage evolution in polymer matrix composites

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ABSTRACT

A 3D Isogeometric Interface-Enriched Generalized Finite Element Method (IIGFEM) is developed to analyze problems with complex, discontinuous gradient fields commonly observed in the structural analysis of heterogeneous materials including polymer matrix composites [1]. In the proposed approach, the mesh generation process is significantly simplified by utilizing simple structured meshes that do not conform to the complex microstructure of the heterogeneous media. Non-Uniform Rational B-Splines, commonly used in computer-aided design, are adopted in the IIGFEM to augment the finite element approximation space and capture the weak discontinuity present along material interfaces. The IIGFEM offers many advantages, such as the simplicity and accuracy of numerical integration, the straightforward implementation of essential boundary conditions, and the flexibility in the choice of the local solution refinement

The ability to model complex material interfaces and the mesh independence are two of key features of the IIGFEM that enable it to tackle problems with evolving material response, such as computational study of damage in solids. Here, we utilize the IIGFEM scheme to study the impact of microstructural details on the initiation and evolution of the damage in polymer matrix composites. For this purpose, in this study, we incorporate a three-parameter isotropic damage model [2] into our IIGFEM solver to capture the fracture response of the matrix in a unidirectional composite layer. To bypass numerical issues associated with mesh bias, we use a viscous regularization scheme proposed by Simo and Ju [3]. The numerical stability of the proposed approach is studied and its advantages and limitations are discussed in detail. Finally, a number of numerical examples are presented to demonstrate the effect of RVE size and filler volume fraction on the damage behavior of fiber-reinforced polymer matrix composites.

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