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Degradation at the Composites Interfacial Zones - A Micromechanical Computational Evaluation Procedure

Ataur R. Syed, Nabi Abolfathi, and Ghodrat Karami

Department of Mechanical Engineering and Applied Mechanics,
North Dakota State University, Fargo, ND 58108-6050, USA.
g.karami@ndsu.edu

Abstract

In this paper, a micromechanics computational algorithm for characterization of structures with unidirectional fibrous composites is introduced. The modeling accounts for the microstructural behavior as well as the interface properties at the microscale where the interface size is highlighted. The interface is simulated by cohesive zone elements. The constitutive materials for the cohesive zone are extracted from the experimental traction-separation relations. Repeating unit cells (RUCs) of the representative volume elements (RVE) of the composite is modeled under specified normal and shear kinematical and loading conditions. The behavior of such unit cells monitor the stiffening and degradation characterization of the composite with the interface stiffening, softening and debonding modeled in an accurate manner. The model is implemented for two examples with linear/nonlinear traction-separation behavior; significant differences in the composite behavior is observed when two different cohesive zone laws were implemented indicating that the shape of the softening zone is important in addition to the initial stiffness and peak stress in cohesive zone law. This micromechanical cohesive zone model is also implemented to examine the impact of adhesion for undulated fibers on the overall composite structure response. The composite strength and stiffness for all the cases examined are compared with the experimental data with good agreements.

Keywords: **Micromechanics, adhesion, interface, cohesive zone, composite structures**

1. INTRODUCTION

The fiber-matrix interface plays an important role in defining key properties such as stiffness, strength and fracture behavior of the modern composite materials used widely in structural and civil engineering applications. In general the global mechanical properties of the material are affected by local failures that include particle (or fiber) splitting, interfacial debonding and matrix cracking [1]. Interface directly influences the load transfer process between the layers and the fiber and matrix. If the materials are essentially insoluble in each other the interface between them will be narrow. In some cases such interface properties can be increased greatly by fiber sizing techniques [2].

Adhesion test is mainly based on the fracture mechanics tests and crack propagation concepts. Pull out test is a widely known method for measuring the adhesion [1]. In modeling, interfacial properties have been evaluated in a number of different ways. By assuming a continuous region with its material properties distinct from the matrix and fiber has been a general approach to model the interaction. However, evaluation of the material properties of this domain is very difficult considering the geometry and scale [3]. The effects of damage due to interfacial decohesion on overall mechanical properties of the composite material have been studied by various authors [4]. A number of numerical models have been proposed and developed over the years to simulate interfacial behavior in composite microstructures. One such method to simulate interfacial behavior is the cohesive zone model, where the interfaces are assumed to be comprised of nonlinear springs of negligible thickness with a specific traction-displacement law. The approach was introduced to analyze interface failure at metal-ceramic interfaces by Needleman [4] and has been used by several researchers including Tvergaard [5] and Ghosh et al.[6]. Tvergaard [5] and Ghosh et. al. [6] have used the cohesive zone model to simulate interface fracture. Ananth and Chandra [8] have used a spring layer model in their numerical analysis and they have found the stress and debonding criterion as well as friction in relative sliding between fiber and matrix. In all these models, special cohesive interface elements, defined by a constitutive equation, are created between the continuum elements. The cohesive elements open with damage initiation and lose their stiffness at failure so that the continuum elements are disconnected. Cohesive elements have been made of two quadrilateral surfaces connecting brick elements [7].