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# Bond-based peridynamic modeling of composite laminates with arbitrary fiber orientation and stacking sequence

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**ABSTRACT**

This study presents a new bond-based peridynamic modeling of composite laminates without any limitation to specific fiber orientation and material properties in order to consider arbitrary laminate layups. Unlike the previous models, it also enables the evaluation of stress and strain fields in each ply of the laminate. Therefore, it permits the use of existing stress- or strain-based failure criteria for damage prediction. The orthotropic material behavior is achieved through the use of in-plane normal, in-plane shear, transverse normal and transverse shear peridynamic bonds. These bonds enable the interaction of material points within each ply as well as their interaction with other material points in the adjacent plies. The micromoduli for each bond type are determined for a square domain of interaction. Also, the inhomogeneous nature of composite materials is included by assigning randomized strength parameters based on Gaussian distribution. The PD equilibrium equation is linearized and solved by employing implicit techniques until immediately before failure occurs. The solution continues by using standard explicit time integration techniques until final failure. The capability of this approach is verified against the benchmark solutions, and validated by comparison with the available experimental results for three laminate layups with an open hole under tension and compression.

*Keywords*: Peridynamics, Composites, Progressive, Failure, Hole, Tension, Compression

## 1 Introduction

It is a very challenging task to predict the failure modes of fiber breakage, matrix cracking, and delamination in composite laminates because of complex damage initiation and growth process. Aside from loading conditions, deformation of a laminate is dependent on the lamina properties, thickness, and stacking sequence. There exists usually an extremely thin resin-rich layer between the laminae; an inherent source for cracking and delamination. Therefore, transverse normal and shear deformations especially play a critical role in the initiation and growth of delamination.

Existing analysis methods face difficulties when predicting all possible failure modes in composites especially under multi-axial loading conditions and multiple-load paths. Recently, the Air Force Research Laboratory (AFRL) conducted a Tech Scout Project in order to evaluate the existing progressive damage prediction methods. As part of this project, the AFRL tested open-hole laminates for three different layups under tension and compression for strength and failure progression. Using the ply level properties of IM7/977-3 composite provided by the AFRL, the participants in this project reported their predictions and comparisons with the test results in a series of papers during AIAA SciTech 2015 [1-8].

As an alternative to the existing methods, Silling [9, 10] introduced the nonlocal peridynamic (PD) theory that does not involve any spatial derivatives. This feature allows

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