A SIMPLE ABAQUS PHASE FIELD IMPLEMENTATION FOR THE STUDY OF TRANSVERSE CRACKING IN COMPOSITE LAMINATES

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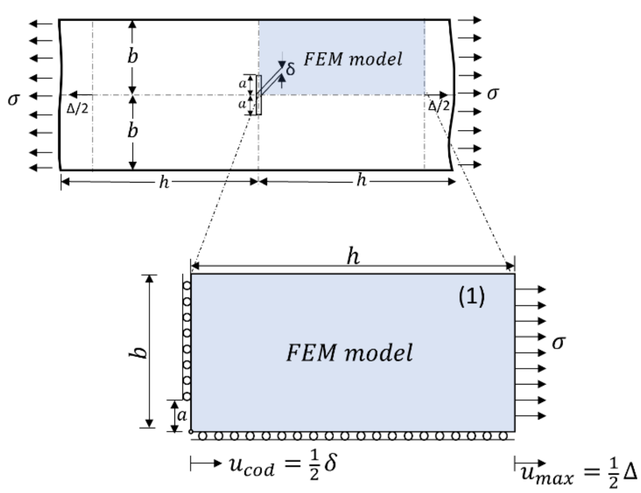
Abstract
In the recent years, phase-field approach has gained remarkable attention in the field of Fracture Mechanics and has offered solutions to numerous problems involving crack onset and propagation. In the present paper, a Abaqus implementation of the phase-field approach using only a user material subroutine is extended to study intralaminar damage in CFRP composites. To this end, the capability of modeling orthotropic elastic behavior, transverse cracks and residual stresses has been introduced in the formulation. To validate the implementation, numerical results were compared with the analytical solution of benchmark problems.

1. Introduction

In fiber reinforced composite laminates, transverse cracking is one of the most serious types of failure mechanisms. Transverse failure and transverse strength of the laminates are significantly influenced by the residual stresses that are developed during the curing of the laminate. The phase-field fracture method implemented in terms of a simple Abaqus UMAT subroutine which takes advantage of the analogy between the phase-field balance equation and heat transfer, presented in [1] for isotropic material behavior is used as a basis for this work and is further extended to account for material orthotropy with transverse damage. To account for residual stresses, the residual strains associated to a uniform decrease in temperature are directly introduced in the Abaqus UMAT subroutine. The implementation is then validated using three different mechanical models and the results are compared with analytical solutions obtained using Linear Elastic Fracture Mechanics (LEFM) [2,3]. All the models were tested with both AT1 and AT2 formulations under monolithic scheme.

2. Results



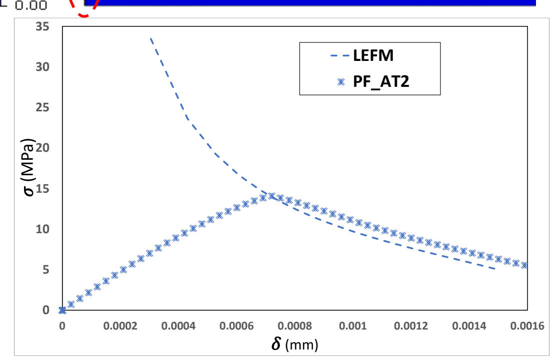


Figure 1: Model-1 (a) Isotropic homogeneous model, (b) Numerical result representing damage after full crack propagation, (c) comparison between numerical and analytical result for stress vs crack opening.

Firstly, to test the implementation, 2D analysis with plane strain, plane stress and generalized plane strain elements are performed on homogeneous isotropic model shown in figure1(a).

All the models were controlled with crack tip opening displacements to avoid large jumps in crack length associated to unstable crack propagation and the results were compared with the LEFM solutions [2]. Figure 1(b) represents one of the results, for a AT2 model with $b = 0.4$ mm and an initial crack length of $b/10$. Figure 1(c) represents a good agreement between the analytical and numerical results for the plot of applied stress versus crack tip opening.

Orthotropic material behavior and transverse damage phase-field implementation is employed in the models shown in figure 2 considering both AT1 and AT2 formulations. Coefficients of thermal expansion were obtained from [2] and results were compared with the LEFM solutions [2,3].

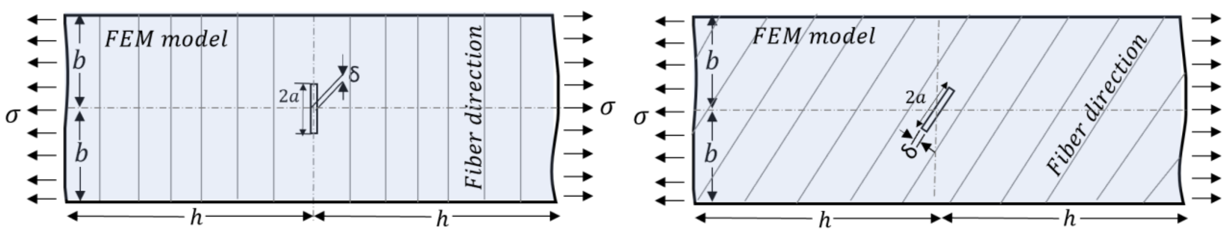


Figure 2: Specimen geometry and boundary conditions (a) Model-2: fibers at 90º (b) Model-3: Fibers at a certain angle θº

3. Conclusions

A phase-field implementation into an Abaqus UMAT for modelling transverse damage in orthotropic material with residual stresses is validated by comparing the numerical results with the analytical solutions using several benchmark problems. This implementation can be easily employed to assess intralaminar and transverse damage in composite laminates with complex geometries (like L-angle, T shaped, omega shaped, etc.).

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