# An adaptive phase-field method to model fracture propagation in orthotropic materials

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Several questions pertaining to the mechanical failure of composites remain unresolved despite significant advances in the composite mechanics. Many existing methods fail to accurately predict the various failure in composites, such as crack deflection, coalescence, and matrix cracking at the laminate interfaces. We extend a recently developed adaptive phase-field method, initially proposed for isotropic material [1], to model delamination in the orthotropic laminated composites. A penalized second-order structural tensor is introduced in the crack-surface density function to facilitate preferential crack growth in the direction of fiber orientation [2]. Furthermore, crack driving force was divided into individual fiber and matrix damage corresponding to different failure modes in the laminate [3]. The primary motivation is to predict the damage regions and complex crack patterns in laminate under various loading conditions by formulating a robust numerical model. This will lead to study different failure mechanisms (translaminar, interlaminar and intralaminar) that prevails in laminate.

In this work, we integrated orthotropic phase-field model with adaptive refinement technique strategy to accurately predict crack propagation in orthotropic materials. The continuity is enforced in weak form through Nitsche's method at the interface of refined and standard elements. The developed approach is then validated through several benchmark numerical experiments revealing the complex fracture mechanics inside composite. The results demonstrate that the crack has an affinity to propagate in the direction of fiber orientation, which is also validated against experimental results. Furthermore, parametric studies are performed to evaluate the damage evolution and maximum load-carrying capacity of the laminate considering interphase material between alternate lamina by varying one property at a time.

It is computationally expensive to perform three dimensional (3D) analysis of composite. A 3D visualization of failure in composite laminate is studied then by conducting two dimensional (2D) analysis of 3D laminate incorporating different orthographic projections (front, side, and top views of laminate). The existing model will study the damage evolution in laminate from meso-scale to macro-scale.

## References

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