# MODELING COMPOSITES WITH ADAPTIVELY INTEGRATED COHESIVE ZONE MODELS

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High-performance composite materials have made steady gains in use for primary structural components over the last few decades. But before a material may be used in a structure, the designer must be able to accurately predict failure. In composites, however, often various damage modes emerge at the micromechanical scale that interact with each other. This coupling of damage modes greatly complicates damage and failure modeling in composites. In order to use composite materials in primary structural components both reliably and efficiently, better models are needed to predict the onset of damage and performance in the presence of damage.

Cohesive zone models (CZMs) can be used to overcome many of these modeling challenges. CZMs have been shown to be a very powerful and flexible tool in modeling fracture and failure in materials. However, when CZMs are included as part of a finite element simulation, numerical limitations have necessitated a very fine mesh in order to reach convergence in the results.[1],[2] Sometimes this convergence problem is so severe that the solver fails completely and the solution cannot be advanced. Often this fine-mesh requirement, together with the memory and processor speeds available, limits the size of the structure that can be simulated to millimeter or centimeter size structures. The CZM convergence problem must be resolved in order to make simulation of large-scale structures with cohesive zone models more practical.

We have found that the convergence problem often exhibited by cohesive zone models is due to the computational implementation of the model and can therefore be resolved by improving the related computational algorithms. Specifically, discontinuous derivatives in the CZM constitutive models introduce errors in the integration of the interfacial traction over the elements. An adaptive integration algorithm is used so that these errors are reduced to an acceptable tolerance, eliminating the dependence of integration accuracy on mesh refinement. This technique allows CZMs to be used with much coarser meshes, with element sizes in some cases as much as two orders of magnitude larger than before. This allows the analysis of much larger, practical structures.

The effectiveness of the improved integration algorithm in correcting the convergence problem is illustrated with a simple double cantilever beam (DCB) example in quasi-static mode I loading. In order to show the capability to simulate practical structures, we show another example of a composite laminate plate subject to impact loading. The finite element model uses cohesive zone elements to simulate delamination and intraply splitting for forty-eight plies in a plate of structural scale (O(1m)). The size of the plate and number of time steps required by the impact dynamics simulation make a fine mesh computationally prohibitive. With the adaptive integration algorithm, however, simulations of structural components of this scale are much more practical.

**References**

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