

# A progressive high-cycle fatigue framework with cycle-dependent cohesive fracture and time-homogenized viscoplasticity

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## Abstract

Modeling high-cycle fatigue delamination is relatively well established for composite specimens with simple geometries and initial delamination fronts. However, there are still challenges for simulating progressive fatigue in more complex composite structures relevant to industry. For instance, in multidirectional laminates, multiple delaminations initiate, propagate and interact with transverse cracks. In these cases, commonly used Paris-type cohesive zone models are not sufficient for describing both initiation and propagation. Furthermore, in thermoplastic composites, viscoplastic deformations develop, which interact with fatigue damage. Moreover, assuming that the local stress ratio at every material point is equal to the global load ratio, as commonly assumed in high-cycle fatigue analyses, is too simplistic when the loading-reloading response is nonlinear. In this contribution, we address the aforementioned challenges and present a mesoscale modeling framework for simulating progressive high-cycle fatigue in polymer composites. The framework combines cycle-dependent cohesive fatigue with time-homogenized viscoplasticity for continuous-fiber reinforced composites. In addition, the effect of varying local stress ratios on the fatigue damage rates is accounted for with an adaptive cycle jumping scheme. The framework is applied to two challenging cases: multidirectional laminates and overmolded thermoplastic composites. For simulating multidirectional laminates, cohesive XFEM is used to describe transverse cracking. Furthermore, the framework is

applied to the simulation of a rib pull-off test on a T-joint, extracted from an overmolded thermoplastic panel. With the presented framework, the effect of viscoplastic deformations, processing-induced mesoscopic geometries and different boundary conditions on the mechanical response is investigated. Finally, the effects of various modeling assumptions and processing parameters are studied, providing relevant insights for optimizing processing parameters and designs of polymer composites.

**Keywords:**

thermoplastic composites overmolding fatigue time-homogenization cohesive zone modeling