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Efficient Numerical Modelling of Adhesive Debonding in Double Cantilever Beam Tests with Geometric and Material Nonlinearity

Leo Škec[1], Damjan Jurković[2], Emina Hadžalić[3], Giulio Alfano[4]

[1] University of Rijeka, Faculty of Civil Engineering, Croatia. leo.skec@uniri.hr
[2] University of Rijeka, Faculty of Civil Engineering, Croatia. damjan.jurkovic@uniri.hr
[3] University of Rijeka, Faculty of Civil Engineering, Croatia. emina.hadzalic@uniri.hr
[4] Brunel University London, Department of Mechanical and Aerospace Engineering, United Kingdom. giulio.alfano@brunel.ac.uk

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Extended Abstract

Abstract

Adhesive bonding is widely employed in automotive, aerospace, and civil engineering, yet the performance of bonded joints is often governed by debonding driven by interfacial fracture. The Double Cantilever Beam (DCB) test is the standard experimental method for characterising Mode I debonding and provides essential parameters for interface damage modelling. Conventional numerical simulation of DCB tests typically relies on two- or three-dimensional solid finite element models, which can be computationally expensive and sensitive to mesh refinement in the fracture process zone. This work presents a novel hybrid analytical–numerical formulation for efficient simulation of adhesive debonding in DCB tests. Closed-form analytical solutions are used to represent the linear-elastic regions of the specimen, while beam-based finite element modelling is confined to the damage process zone, where progressive adhesive degradation occurs. Crack propagation is handled through an automatic crack-tracking remeshing algorithm that relocates a stack of finite elements along the interface as the crack advances, with the remaining structure treated analytically. By exploiting the symmetry of the DCB configuration, only half of the specimen is modelled, and the adhesive response is embedded as a spring foundation within the beam formulation, enabling a unified representation of adhesive failure and beam deformation. The formulation is developed for both linear and geometrically nonlinear analyses, allowing large displacements and rotations to be captured, and includes elastic–plastic bending behaviour of the arms with linear isotropic hardening. When geometric or material nonlinearities are considered, efficient beam finite element formulations are employed in place of analytical solutions in the debonded regions. The proposed approach significantly reduces computational cost compared to conventional solid-element models while retaining accuracy in predicting crack initiation and propagation.

Keywords:

adhesives debonding fracture mechanics damage double cantilever beam finite element method analytical solution