T-spline-based isogeometric treatment of mixed-mode debonding

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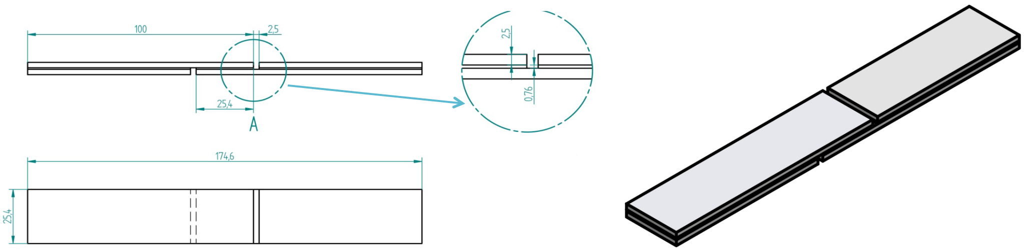
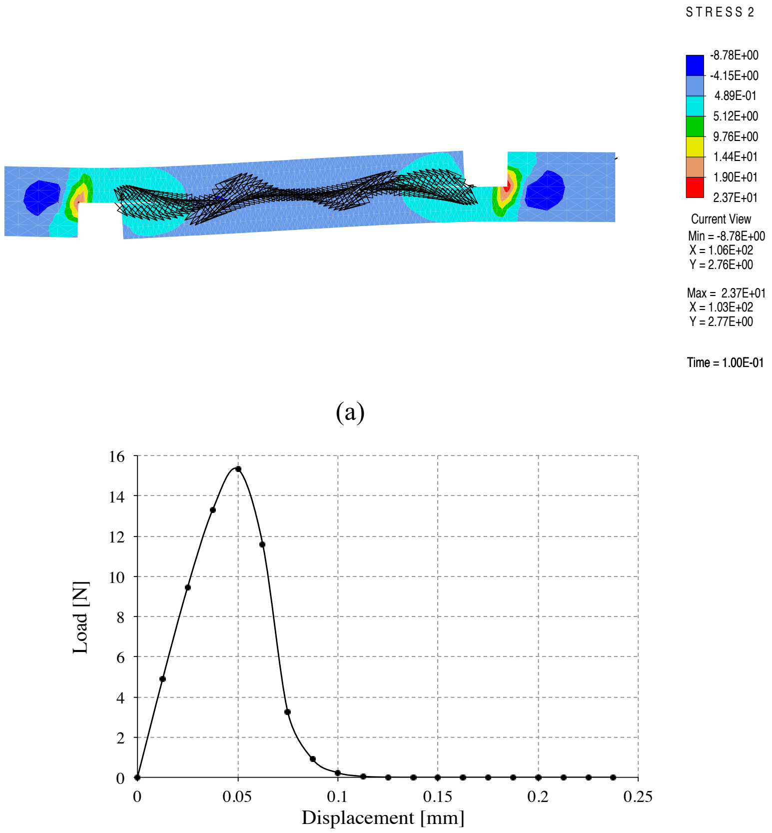
In a context where adhesive-bonded joints are increasingly used in aerospace and automotive industries, prediction of interfacial and cohesive failure mechanisms is an important issue, that has to be treated both analytically and numerically. To this end, a successfull numerical tool dealing with failure prediction of adhesive joints is available in literature using standard low order finite elements relying on Lagrange polynomial bases. The two most popular numerical methods for the analysis are the Virtual Crack Closure Technique [1, 2] and interface elements with cohesive zone (CZ) laws [3, 4]. The numerical application of CZ models for debonding problems within finite element frameworks, however, usually suffer from unphysical stress oscillations at large stress gradients unless fine meshes discretize the fracture process zone ahead of the crack tip.

An innovative framework where better geometrical accuracy is combined with higher and tailorable inter-element continuity is provided by isogeometric analysis, as here adopted to describe the interface damage mechanisms for adhesively-bonded interfaces in mixed-mode conditions. The debonding process along the adhesive interfaces are herein treated with CZ modeling by adopting "analysis-suitable" T-splines discretizations of the meshes. The interface is discretized with zero-thickness contact elements which encompass both contact and mixed-mode debonding within a unified framework, using a Gauss-point-to-surface formulation [5]. A coupled exponential cohesive interface constitutive law is then employed to treat the debonding phase, where all the components (I and II) of the traction vector depend on all the components of the interface separation. The methodology is explored for bi-dimensional composite-to-composite single-lap-joint specimens [6], composed of four composite substrate segments bonded by thin layers of adhesive (Figures 1a,b). The numerical results (see Figures 2a,b) show that mixed-mode CZ models combined with T-spline-based discretizations allow for a very accurate and robust treatment of debonding phenomena and are compared to standard linear and higher-order Lagrange interpolations.



(a) Geometry (b) Specimen

Figure 1: Single-lap joint problem (ASTM D3165).



(a)

(b)

Figure 2: Single-lap-joint problem: local (a) and global (b) response.

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