IGA-based cohesive zone modeling for mixed-mode debonding

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Cohesive zone (CZ) models are increasingly used, by the scientific community, to analyze the mixed-mode progressive damage of laminated or jointed structures. These models describe the traction-separation behavior of interfaces before and during fracture, and are characterized by two phases, i.e. an increase of the traction up to a peak value and a subsequent decrease to zero, which describe the crack initiation and the growth of cohesive surfaces until new traction-free surfaces appear. The FEM modeling of CZ models for debonding problems suffers from an intrinsic discretization sensitivity. Indeed, a sufficiently accurate approximation of the fracture process zone (FPZ) is needed to limit the iterative convergence problems due to possible unphysical (numerical) snap-through or snap-back branches in the load-deflection response. The simplest strategy to deal with this problem consists in reducing the oscillations through mesh refinement, so that the FPZ is adequately resolved. In this context, an isogeometric discretization of a mesh guarantees an exact description of the geometry, combined with the possible achievement of the desired degree of continuity at the element boundaries. This leads to substantial advantages in the computational treatment of unilateral contact and single-mode debonding problems, as recently demonstrated in the literature [1-4]. The present contribution deals with an isogeometric CZ modeling of interface debonding, where the path of the debonding crack is known *a priori*. The continuum is discretized with cubic T-splines, as well as with cubic Non Uniform Rational B-Splines (NURBS) and Lagrange polynomial elements for comparison purposes. A thermodynamically consistent exponential mixed-mode CZ model, as proposed in [5], is herein implemented into a generalized Gauss-point-to-surface contact element to treat the inelastic decohesion process. In the normal direction under compression the non-penetration condition is enforced using the penalty method. The debonding model is thermodynamically consistent and accounts for loading and unloading conditions, as well as for decohesion and contact. Results for a mixed-mode debonding test with varying resolutions of the process zone and varying number of Gauss points used for the enforcement of the contact constraints are presented and compared. The superior accuracy of isogeometric interpolations with respect to the Lagrange ones for a given number of degrees of freedom is verified.

References

[1] De Lorenzis, L., Temizer, I., Wriggers, P., and Zavarise, G., "A large deformation frictional contact formulation using NURBS-based isogeometric analysis", *Int. J. Numer. Meth. Engng.*, **87(13)**, 1278-1300 (2011).

[2] Dimitri, R., De Lorenzis, L., Scott, M.A., Wriggers, P., and Zavarise, G., "Isogeometric large deformation frictionless contact using T-splines", *Comput. Methods Appl. Mech. Engrg.*, **269**, 394-414 (2014).

[3] Dimitri, R., De Lorenzis, L., Wriggers, P., and Zavarise, G., "NURBS- and T-spline-based isogeometric cohesive zone modeling of interface debonding", *Comput. Mech.*, **54**, 369-388 (2014).

[4] Dimitri, R., "Isogeometric treatment of large deformation contact and debonding problems with T-splines: a review", *Curved and Layer. Struct.*, **2**, 59-90 (2015).

[5] Dimitri, R., Trullo M., De Lorenzis, and Zavarise, G., “Coupled cohesive zone models for mixed-mode fracture: a comparative study”, *submitted*.