Cohesive Fracture Analysis using Powell-Sabin B-splines

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ABSTRACT

The computational modelling of crack propagation is of crucial importance for understanding and predicting fracture in quasi-brittle materials such as concrete. In contrast to purely brittle fracture, the failure process in quasi-brittle materials takes place in a zone where normal and shear tractions can be transferred across the crack surface due to interlocking and friction. The cohesive zone model introduced by Dugdale and Barenblatt is a commonly employed model to consider this process zone [1]. The cohesive zone model considers that crack nucleation progresses steadily and the material loses its load-bearing capacity gradually. To describe this model mathematically, the traction in the fracture zone is related to the crack opening by a traction-opening law. The cohesive zone model can be easily incorporated in the finite element formulation (FEM), especially in the case that the crack path is pre-defined, e.g., the delamination of composite structure. In general, the challenge of implementing the cohesive zone model in FEM lies in the description of internal crack interfaces. Over the past decades, various FEM technologies have been presented to capture the crack interface, such as interface elements and embedded discontinuities. Recently, the isogeometric analysis (IGA) has also been introduced in the context of crack propagation analysis [1, 2]. The crack segment is represented by NURBS or T-spline basis functions. IGA can accurately predict the local stress field. However, NURBS and T-splines have some limitations when modelling (cohesive) fracture, and a discrete representation of a crack fails in some situations. This restriction is due to the crack segment insertion in the parameter domain and the reparameterization in the physical domain [2].

In this contribution, we employ Powell-Sabin B-splines, which are based on triangles, to model cohesive crack propagation. The crack is introduced directly in the physical domain. Due to the use of triangles, re-meshing is more straightforward. To implement the proposed method in existing finite element programs, Bézier extraction is employed. The accuracy of the approach to model free crack propagation is demonstrated by several numerical examples, including an L-shaped beam and the Nooru-Mohamed concrete panel.

REFERENCES

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