Computational shortcuts to extract cohesive zone laws in steady-state plate tearing under mixed mode loading conditions

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ABSTRACT

Fracture in large-scale plate structures is typically dealt with by exploiting shell elements combined with so-called cohesive elements to discretize the topology. This allows for an efficient treatment of complex material failures and is an alternative to the mesh-dependent micromechanically-based Gurson model, which is computationally costly. However, engineers tend to employ very simplistic traction-separation laws, which do not reflect the severe thinning, shear localization and the process of void growth to coalescence observed in ductile plate tearing.

One way to extract more accurate cohesive zone laws for steadily growing cracks in large plate structures is by using plane strain elements as laid out in Nielsen and Hutchinson [1] for Mode I loading. However, even though this is a simplified set-up, it becomes computationally costly when investigating Mode I-Mode II loading due to the necessity of a 3D-framework. Such a model would lead to non-trivial boundary conditions to enforce a plane strain condition to the necessary 3D-framework.

A new-thinking procedure to tackle the 3D-framework for mixed mode failure is to describe a 2D-type plane element but in 3D. Here, by adding degrees of freedom in each node, this allows out-of-plane deflection for the otherwise plane geometry. With this approach, it is possible to describe the 3D deformation restricted to plane strain conditions with only a fraction of the cost that the full 3D model poses.

This new element, implemented in an in-house finite strain code, makes it possible to investigate the Mode I-Mode II as well as the Mode I-Mode III load case for a variety of mode mixities. The cohesive fracture energy, peak stress, and appearance of the traction-separation response has been examined and compared to the typically assumed rotational sweep of simplistic traction-separation laws [2] accepted in literature as well as by commercial finite element software [3].

REFERENCES

[1] Nielsen, K.L. & Hutchinson, J.W., *Cohesive traction-separation laws for tearing of ductile metal plates*, International Journal of Impact Engineering 48, 15{23 (2012).
[2] Hogberg, J.L., *Mixed Mode Cohesive Law*, International Journal of Fracture 141.3-4 (2006): 549–559.
[3] Abaqus 2016 Analysis User’s Guide – Chapter 32.5.6