Combination of XFEM and CZM for the numerical simulation of ductile fracture

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ABSTRACT

The present work aims at the numerical prediction of the current residual strength of large, naval or aeronautical, metallic structures in their design regarding accidental overloads as encountered notably during collision, explosion, impact, etc. An accurate prediction requires accounting for the three main stages leading to the ultimate ductile fracture, viz. more or less diffuse damage coupled with plasticity (stage 1), strain localisation (stage 2) and then crack formation (stage 3). A unified methodology allowing at numerically reproducing the consequences of the consecutive aforementioned stages is presented.

The first stage (stage 1) of diffuse damage is characterized by the germination and growth of micro-voids. The material response in this stage is assumed to be governed by the micro-porous plasticity GTN yield function [1] within the standard finite element method (FEM) framework. For the final stage (step 3), corresponding to crack formation, the eXtended finite element method (XFEM), as applied by Crété et al. [2] for ductile metals, has been shown to well reproduce the kinematic consequences of the presence of a traction free crack within a structure.

The second stage (stage 2) corresponds to the micro-void induced strain localization within a narrow band. In the present approach the band induced weak discontinuity is considered as a cohesive strong discontinuity. The progressive loss of matter cohesion in the band leads ultimately to the formation of the crack induced genuine strong discontinuity. From the numerical perspective, this stage is accordingly described by coupling a cohesive segment and a strong discontinuity in the XFEM formulation as proposed by Wolf et al. [3]. Criteria for the transition between the different steps are proposed notably based on bifurcation analysis.

The unified three-dimensional methodology has been implemented as user element subroutine (UEL) within the commercial finite element computation code ABAQUS and its feasibility is shown considering the 3D numerical simulations of the tension loading of a flat specimen. The influence of the cohesive zone model adopted is discussed as well as the mesh objectivity.

REFERENCES

[1] V. Tvergaard and A. Needleman,1984, Analysis of cupcone fracture in a round tensile bar. Acta metallurgica, 32(32) :p.157-169.

[2] J. P. Crété, P. Longère and J. M. Cadou, 2014, Numerical modelling of crack propagation in ductile materials combining the GTN model and X-FEM, Comp. Meth. Appl. Mech. Eng. 275, 204-233.

[3] J. Wolf, P. Longère, J. M. Cadou and J. P. Crété, 2018, Numerical modeling of strain localization in engineering ductile materials combining cohesive models and X-FEM, Int. J. Mech. Mat. Design. 14, 177-193.