11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

JOINT COMPUTATIONAL AND ANALYTICAL APPROACH TO CHARACTERIZE SELF-SIMILAR CRACK PROPAGATION WITH THE THICK LEVEL SET DAMAGE MODEL

Andrés PARRILLA GÓMEZ[1], Claude STOLZ[1,2], Nicolas MOËS[1]

[1] GeM Institute, UMR CNRS 6183 École Centrale de Nantes, 1 rue de la Noë, Nantes, 44321, France

[2] LaMSID EDF-CEA-CNRS UMR 8193 Avenue du Général de Gaulle, Clamart, 92141, France

contact: [andres.parrilla-gomez,claude.stolz,nicolas.moes]@ec-nantes.fr

Key words: *Damage, Thick Level Set, Crack Propagation*

The initiation and growth of cracks play an important role in structural behaviour of quasi-brittle materials such as concrete. Thus an accurate and efficient modelling of such phenomena is strongly needed. However, fracture mechanics is not generally adapted to the modelling of the degradation of such solids under mechanical loading. The initiation of defects requires damage modelling in order to describe the gradual loss of local stiffness. Damage is usually modelled by a scalar variable d, which value is 0 for undamaged material and 1 for totally damaged one. The classical model is local and is governed by a normality rule. The locality of this model leads to spurious localisation in computational simulations: damage is concentrated in a zone of unphysical size (similar to the elements size). Several approaches are useful to solve this problem. For instance, averaging quantities over a zone with some characteristic length [1], constitutive laws based on damage gradient [2, 3] or on deformation gradient [4], phase-field methods [5] or variational approaches [6] have been proposed for this purpose. All these methods impact the classical local models over the whole domain at all time.

To reduce computation time, a new approach was introduced in [7], [8] and [9] called Thick Level Set damage model. TLS reduces the non-locality to a small area in the domain. Damage is assumed to be zero all over the rest of the domain. The TLS model is also able to deal with local non-zero damage but this case will not be addressed in this paper. In the non-local damaged area, damage value only depends on the distance to its boundary, which is called damage front. Damage increases continuously from 0 to 1. Total damage $d = 1$ is reached at a distance l_c from the front. One of the most important advantages of this model is to easily link damage models with fracture mechanics: a totally damaged zone naturally appears when damage front moves in the material. It is simply located by the level set of value l_c. X-FEM [10] enrichment is then used to allow discontinuous displacements across the crack.

Such a model introduces a characteristic length l_c but also a function $d(\phi)$ representing damage dependence on the level-set. Thus results depend on the choice of l_c and $d(\phi)$. The influence of this function is studied in the case of an self-similar quasi-crack propagation in mode III in an homogeneous elastic material. A joint computational and analytical study is performed. Computationally, a shape optimization algorithm is used to determine the damage front form when propagating with different damage laws. Analytically, asymptotic solutions at $d \to 1^-$, *i.e.* around crack tip, have been elucidated for given front shapes.

REFERENCES

[1] Pijaudier-Cabot, G. and Bazant, Z. P. Nonlocal damage theory. *Journal of Engineering Mechanics*, Vol. **113(10)**, 1512-1533, 1987.

[2] Frémond, M. and Nedjar, B. Damage, gradient of damage and principle of virtual power. *International Journal of Solids and Structures* Vol. **33(8)**, 1083-1103, 1996.

[3] Pijaudier-Cabot, G., Burlion, N. (1996). Damage and localisation in elastic materials with voids. *Mechanics of Cohesivefrictional Materials*, **1(2)**, 129-144.

[4] Triantafyllidis, N., Aifantis, E. C. (1986). A gradient approach to localization of deformation. I. Hyperelastic materials. *Journal of Elasticity*, **16(3)**, 225-237.

[5] Karma, A., Kessler, D. A., Levine, H. (2001). Phase-field model of mode III dynamic fracture. *Physical Review Letters*, **87(4)**, 045501.

[6] Francfort, G. A., Marigo, J. J. (1998). Revisiting brittle fracture as an energy minimization problem. *Journal of the Mechanics and Physics of Solids*, **46(8)**, 1319-1342.

[7] Moës, N., Stolz, C., Bernard, P.-E., Chevaugeon, N. (2011). A level set based model for damage growth: the thick level set approach. *International Journal for Numerical Methods in Engineering*, **86(3)**, 358-380.

[8] Bernard, P.-E., Moës, N., Chevaugeon, N. (2012). Damage growth modeling using the Thick Level Set (TLS) approach: Efficient discretization for quasi-static loadings. *Computer Methods in Applied Mechanics and Engineering*, **233**, 11-27.

[9] Stolz, C., Moës, N. (2012). A new model of damage: a moving thick layer approach. *International journal of fracture*, **174(1)**, 49-60.

[10] Moës, N., Dolbow, J., Belytschko, T. (1999). A finite element method for crack growth without remeshing. *International Journal for Numerical Methods in Engineering*, **46**, 131-150.