Robust solvers for “Lip-field” damage models

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Models formulated within the framework of the Continuum Damage Mechanics are often used to simulate cracking in quasi-brittle materials. However, when the material softens, the solution to the equilibrium problem is no longer unique. In the context of the finite element method, this leads to a pathological dependence on the finite element mesh used to discretize the computational domain.

Moës and Chevaugeon [1, 2] recently proposed a new way to avoid spurious localizations. The idea is to impose a Lipschitz regularity on the internal variables controlling material softening. Such a regularity constraint introduces a characteristic length into the formulation. The solution to the problem is sought by alternated minimization of a convex incremental energy potential with respect to the unknown displacement and damage fields. The convex Lip-field condition is added as an additional constraint in the alternating minimization. Upper and lower bounds built from a prediction of the local evolution of the field of damage make it possible to optimize the search for the regularized damage field.

The first aspect treated in this contribution concerns the formulation of the minimization problem to be solved for computing the regularized damage field. It is shown that if the desired solution is obtained by combining the upper and lower bounds, the minimization problem can be rewritten differently, and the resulting numerical formulation gains in stability while keeping a final solution respecting the Lipschitz constraint. Calculation times are also reduced.

The second aspect concerns the formulation of path-following solvers dedicated to the ”Lip-field” approach to damage. Adapting the external loading during the calculation (see e.g., [3, 4, 5]) to control the evolution of the material non-linearities is helpful to obtain a solution even in the presence of structural instabilities and to reduce the number of iterations to convergence. This second aspect is of paramount importance. Indeed, using indirect loading control algorithms (if well chosen and formulated) can significantly reduce the number of iterations to converge in the context of an alternated minimization solver.

After illustrating the numerical formulations, some one-dimensional and two-dimensional test cases are presented.

References

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