Non intrusive implementation of a gradient formulation based on the nonlocal Eikonal approach

Florian Marconi[*], **Emmanuel Baranger**[†] **and Rodrigue Desmorat**[†]

[*] LMT, ENS Cachan, CNRS, Université Paris Saclay
61 avenue du President Wilson, 94230, Cachan
e-mail: [marconi ; baranger ; desmorat] @lmt.ens-cachan.fr

ABSTRACT

Due to the ill-posedness of problems using local damage models with strain softening, the size of the localization area where damage appears is not fixed. Such models thus exhibit a strong mesh dependency when implemented in classical finite element codes, since localization then appears in a single element.

To address this issue, regularization methods called nonlocal have been proposed in the literature allowing convergence toward physically realistic solutions, namely with a finite non zero dissipated energy. The original idea for such approaches, introduced in [1], was to impose a non zero and mesh independent dissipated energy. To do so the authors decided to replace the variable driving damage by its nonlocal counterpart, obtained through a spatial weighted average over a finite zone. This nonlocal treatment thus introduces an internal characteristic length, setting the size of the localization area.
However, when working with this formulation one may face issues linked to the numerical computation of the spacial average. The gradient formulation proposed in [2] and based on the first one seems to have the same regularisation properties without the numerical average issues.

Nevertheless those approaches require to take some precautions as showed in [3], especially regarding the choice of the nonlocal variable. Some choices can induce a non-physical post-pic behaviour, like the stress-locking obtained with nonlocal damage. It is also essential to ensure that the nonlocal treatment does not affect the elastic response, which could occur when applied on the strain tensor.
Moreover, those approaches can not be used to precisely depict a crack since interactions do not vanish through a "pseudo-crack" (defined as $D = 1$ area in presented approach).

A new regularisation method was proposed in [4] where the distances used for the average are replaced by propagation times. This approach can unaffectedly be used for both isotropic and anisotropic damage, and since the wave speed depends on damage, the nonlocal treatment will evolve with it.
Thus, using this approach, one gets mesh independent results while cutting all interactions and recovering crack behaviour where $D = 1$.
An alternative formulation with the same properties has been established in [4], replacing the propagation time with lengths computed in a space curved by damage. Following Peerlings work [2], an approximated gradient formulation has also been established in [4] and will be studied here.

We will detail a first non intrusive implementation of this so-called eikonal formulation, which makes use of the Abaqus built-in thermomechanical solver and allow us for performing dissipation driven computations. The first results obtained with this implementation are encouraging and will be presented in this paper.

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