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GRADIENT OF DAMAGE ENHANCEMENT FOR A COHESIVE MODEL

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Gradient enhancements have become increasingly popular in the last decades for dealing with problems in mechanics suffering from spurious mesh sensitivity induced by strain softening. Many proposals exist in this sense and various regularization techniques have been presented and successfully applied to study localization and fracture.

In short, the idea underlying almost all such techniques is that of using some extended constitutive equations in which information about the material microstructure is represented through a length scale-related parameter. The physical interpretation of this quantity on a micromechanical basis is still the object of an open debate, whereby its interpretation as a mere numerical regularization parameter is certainly more appropriate.

From a computational standpoint, once spatial gradients and/or length scales are introduced in the constitutive equations the latter are no longer defined at the local (quadrature point) level but they are established at a larger scale, i.e. the scale of the structural model, in a form that could be rephrased in an integral format. Basically, for usual local models stresses, strains and internal variables are defined in a point-wise fashion whereby, as outlined in [1], their values can be regarded as the parameters of a piece-wise constant interpolation. Hence, variables computed at the Gauss point level in classical displacement-based finite element methods can be understood as fields that are in general discontinuous across elements boundaries and inside elements as well. This discontinuous pattern is indeed one of the most striking consequences of the strictly local character of the constitutive law.

Contrariwise, for nonlocal and gradient-enhanced models the presence of gradient or averaging operators in the constitutive equations enforces a greater regularity of strains, stresses and internal variables and the resulting solution will be globally smoothed through elements. Moreover, increased regularity in general characterizes the entire solution and is not limited to the gradient-enhanced variables.

In this work reference is made to an interface cohesive model originally proposed in [2]. When considering the simplest two-parameter version for the mode I case, damage evolution is governed by the following relationships:

$$f(D) \leq 0; \qquad \dot{D} \geq 0; \qquad f(D)\dot{D} = 0 \tag{1}$$

for the damage function:

$$f(D) = Y + G_c \log(1 - D) \tag{2}$$

being $D \in [0, 1]$ the scalar damage variable, Y the (local) damage-driving force and G_c the mode-I fracture energy. The gradient enhancement can be introduced using different arguments, see e.g. [3, 4, 5] among others, and the evaluation of the damage state now amounts to solving the complementarity problem (1) with

$$g(D) = c\nabla^2 D + Y + G_c \log(1 - D) \tag{3}$$

in place of the local damage function (2). In the above relationship c is a model parameter having the dimensions of a force that can be related to the characteristic length scale. Moreover, owing to the presence of spatial derivatives in the damage function (3), the computation of the damage state requires the solution of a boundary value problem.

Numerical results that are being presented in this communications will show the superior performances of the damage enhanced model with reference to typical fracture propagation tests, where the gradient model provides meaningful answers quite independently from the mesh size.

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