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Modelling of strain localization in brittle and ductile materials via a two-scale formulation

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ABSTRACT

Strain localization phenomena usually precede the failure of different solid bodies. In the case of brittle materials like concrete the failure is due to the material fracture, in ductile materials like metals under certain stress/strain conditions, a very narrow localized zone of intense plastic shearing can occur: this phenomenon is called shear banding.

The modelling of a solid body up to its ultimate loading usually requires the capability of modelling the strain localization phenomena.

The difficulty in modeling strain localization phenomena using standard finite element formulations lies in the different scales that need to be used for the description of the global deformation in the continuum and the localized deformation along zero width lines.

When standard finite element formulations are used for modeling brittle fracture or shear banding, the width of the localized zone is forced to be in the elements size scale; hence the results are mesh-dependent.

For modeling the fracture of brittle materials like concrete, rocks and ceramics, the fracture initiation is defined by a tensile stress larger than a threshold value and during fracture propagation we can observe a softening in the load-displacement response; since a local constitutive relation showing strain softening was proved to be thermodynamically unacceptable the phenomenon is modeled introducing a fractomechanics concept: the fracture energy, which has been shown to be a material property. The different finite element methodologies that were developed for modeling the fracture process in brittle materials are:

- The smeared crack approach.
- The discrete crack approach.
- Finite elements with embedded discontinuous strain fields.

- Finite elements with embedded discontinuous displacement fields [1-2]

Regarding ductile materials, many techniques have been proposed for shear band modeling:

- Enhanced strain field.
- Extended finite element method (X-FEM).
- Unfitted finite elements techniques.
- Embedded localization modes [3]

The techniques discussed in [1-3] can be unified under the category of two-scale formulations, in which a fine scale is used to model the localization phenomena (fracture in brittle materials and shear banding in ductile materials). These techniques provide mesh-independent results.

In order to optimize the accuracy of the numerical results, the techniques developed in Refs. [1-3] were implemented in the QMITC element that has shown a good capability for modeling plastic localization [4].

In this paper we present numerical examples for the case of ductile materials modeled using either von Mises or Gurson plasticity models.

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