Sources of error and limit of applying the energetic-based regularization method

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Abstract

As it is well-known, using damage models or damage-plastic models in computational failure analysis leads automatically to mesh dependency. This numerical aspect is originally caused by the loss of ellipticity of the local equilibrium equations (under static loading). Various regularization techniques are used to restore the objectivity of the mechanical description (non-local formulation or by incorporating a displacement discontinuities [1,2]). A practical efficient technique mostly used in practical engineering is based on the crack band theory [3]. The constitutive law is adjusted such that the fracture energy dissipated is preserved. Practically, this is achieved by adjusting the softening part of the stress-strain diagram. The fracture energy, which is mathematically evaluated by integrating the area under the stress-strain diagram, is reached only if this integral is definite. This could be simply reached by considering a suitable damage evolution law when using damage models. However when plasticity is considered, the evaluation of the area under the stress-strain diagram is complicated by the fact that the plastic strains are not explicitly related to the total strains. The plastic strains evolution is driven by the loading function using the normality rule. Therefore, when using damage-plastic models, if the fracture energy is evaluated by considering only the damage part, this leads to a non-realistic dissipation.

Another problem is related to the use of this regularization technique in 2D or 3D computational analysis. In order to adjust the softening part of the non-linear model, the fracture energy is generally evaluated considering a uniaxial stress state. However, even if the finite element is under mode I failure, during the computation analysis, the presence of other stress tensor components leads to a biaxial stress-state or a more complicated stress-state. Hence, matching the fracture

energy under a uniaxial stress relationship leads to a misprediction of the dissipated energy in reality.

In the present paper, the two aspects cited above are discussed in order to fix the sources of errors related to the use of this technique. The computational/numerical aspects are illustrated on structural examples.

References

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