

A nonlocal scheme of integral-type for heterogeneous ductile materials

F.J.P. Reis, I.A.R. Lopes, F.M. Andrade Pires*, F.X.C. Andrade

* DEMec - Department of Mechanical Engineering,
Faculty of Porto, University of Porto
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Email: fpires@fe.up.pt - Web page: <https://sigarra.up.pt/feup/pt>

ABSTRACT

The prediction of the mechanical behaviour of heterogeneous ductile materials undergoing finite strains and subjected to arbitrary conditions, possibly leading to damage and failure, is extremely important for a wide variety of applications including structural engineering, forming operations, collision of solids, among others. Therefore, considerable efforts have been made by the academic community to understand the deformation behaviour of these materials and to develop constitutive models that are able to capture the experimentally observed response.

A promising strategy to model the behaviour of these materials consists in using a confined model of the microstructure, usually known as unit cell or representative volume element (RVE), which incorporates all statistically relevant microstructural features, to capture the material constitutive response [1, 2, 3]. The so-called micromechanical approach requires the solution of a boundary value problem of the RVE based on the knowledge of the macroscopic deformation tensors and internal variables, to obtain the macro stress from a homogenization procedure.

Unfortunately, the use of material constitutive models with softening, which are typically developed to capture the material internal degradation (or damage), can lead to the loss of ellipticity of the governing equilibrium equations after the onset of strain-softening. Consequently, the boundary value problem becomes ill posed and the associated finite element solution becomes dependent of the spatial discretization [4, 5]. Therefore, in order to minimize this mesh dependence pathology, several non-local approaches have been developed over the last years.

In this work, a non-local scheme of integral type is proposed for the homogenization of heterogeneous ductile materials at finite strains. The constituents and phases of the material at the microstructural representative volume element (RVE) level are modelled with a nonlocal elastoplastic isotropic damage model. The numerical integration of the constitutive equations within a nonlinear homogenization problem is undertaken together with the derivation of the consistent nonlocal tangent operator. The quadratic rate of convergence of the Newton-Raphson iterative procedure is achieved at finite strains. The scheme is applied to the simulation of ductile damage and the capability to alleviate the pathological mesh dependence is illustrated with different microstructures.

REFERENCES

- [1] F. Costanzo, A. D. Boyd, J.G., “Micromechanics and homogenization of inelastic composite materials with growing cracks”, *J. Mech. Phys. Solids*, **44**, (3) 333-370 (1996).
- [2] S. Ghosh, K. Lee, P. Raghavan, “A multi-level computational model for multiscale damage analysis in composite and porous materials”, *Int. J. Solids Struct.*, **38**, 2335-2385 (2001).
- [3] F. Souza, D. Allen, Modeling failure of heterogeneous viscoelastic solids under dynamic/impact loading due to multiple evolving cracks using a two-way coupled multiscale, *Mech. Time Depend Mater.*, **14**, (2) 125-151 (2010).
- [4] Z. Bažant, F.-B. Lin, Nonlocal yield-limit degradation, *Int. J. Num Meth. Eng.*, **26**, 1805-1823 (1988).
- [5] M. Jirasek, Nonlocal models for damage and fracture: comparison of approaches, *Int. J. Solids Struct.*, **35** 4133-4145 (1998).