An incremental variational procedure for elasto-plastic composites with combined isotropic and linear kinematic hardening

Antoine Lucchetta[a], François Auslender[b], Michel Bornert[c] , Djimédo Kondo[a]

a. Université Pierre et Marie Curie, Institut Jean le Rond d'Alembert, Paris, France
E-mail : antoine.lucchetta@upmc.fr, djimedo.kondo@upmc.fr
b. Université Clermont Auvergne, Institut Pascal, Clermont-Ferrand, France
E-mail : francois.auslender@uca.fr
c. Université Paris-Est, Laboratoire Navier, Marne-la-Vallée, France
E-mail : michel.bornert@enpc.fr

MOTS CLES : incremental variational procedure, isotropic and kinematic hardenings, composites

RESUME

In this study, we investigate the nonlinear behavior of elasto-plastic composites with isotropic and kinematic hardening. For this, we rely on the incremental variational principles introduced by Lahellec and Suquet [2]. We also take advantage of an alternative formulation, recently proposed by Agoras et al. [1] for visco-plastic composites without hardening, which consists in a double application of the variational procedure (VP) of Ponte-Castañeda. We extend this approach to elasto-plastic composites with hardening. The first application of the VP linearizes the local behavior, including hardening, and leads to a thermo-elastic Linear Comparison Composite (LCC) with an heterogeneous polarization field inside the phases. The second one dealt with the heterogeneity of the polarization and results in a new thermo-elastic LCC with an homogeneous polarization inside the phases. Its effective behavior can then be estimated by the classical linear homogenization schemes.

We developed and implemented this new incremental variational procedure for composites comprised of elastic spherical particles isotropically distributed in an elasto-plastic matrix with isotropic and linear kinematic hardening. The predictions of the model are compared with results available in the literature for cyclic loadings, e.g. [3]. New results for elasto-plastic composites with combined isotropic and kinematic hardenings are also provided. At both local and macroscopic scales, they are in good agreement with the numerical computations we carried out.

REFERENCES

[1] Agoras M., Avazmohammadi R., Ponte Castañeda P., Incremental variational procedure for elasto-viscoplastic composites and application to polymer- and metal-matrix composites reinforced by spheroidal elastic particles, International Journal of Solids and Structures, 97-98, 668-686 (2016).

[2] Lahellec N., Suquet P., On the effective behaviour of nonlinear inelastic composite: I. incremental variational principles, Journal of the Mechanics and Physics of Solids, 55, 1932-1963, (2007).

[3] Lahellec N., Suquet P., Effective response and field statistic in elasto-plastic and elasto-viscoplastic composites under radial and non-radial loading, International Journal of Plasticity, 42, 1-30 (2013).