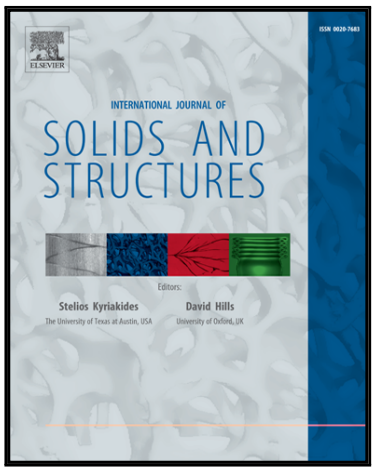

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M. Agoras, R. Avazmohammadi, P. Ponte Castañeda

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Incremental variational procedure for elasto-viscoplastic composites and application to polymer- and metal-matrix composites reinforced by spheroidal elastic particles

M. Agoras[a], R. Avazmohammadi[b], P. Ponte Castañeda[c]

[a] *Department of Mechanical Engineering, University of Thessaly, Volos 38334, Greece*

[b] *Institute for Computational Engineering and Sciences, University of Texas at Austin, TX 78712, U.S.A.*

[c] *Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA 19104, U.S.A.*

Abstract

This paper presents an alternative formulation of the incremental variational procedure (IVP) of Lahellec and Suquet (2013) to estimate the macroscopic response and field statistics in elasto-viscoplastic composites. The basic idea is to make use of a time-incremental variational formulation for the strain-rate potential of the elasto-viscoplastic composite, to define a homogenization problem for a viscoplastic composite with non-uniform "eigenstrain rates" in the phases. Both the nonlinearity and the heterogeneity of the properties in the phases can then be handled by means of the variational procedure of Ponte Castaneda (1992) in terms of a suitably optimized linear comparison composite with uniform properties, for which standard homogenization estimates are available. The IVP is then applied to two-phase composites consisting of aligned, ellipsoidal elastic particles in an elastic-ideally plastic matrix and the effects of the particle concentration and shape, as well as the properties of the matrix and particles, are investigated. Upon uniform strain-rate loading, three regimes of deformation are observed: a linear, purely elastic regime, followed by a transient elasto-plastic regime, and then a steady-state ideally plastic regime. It is found that the more compliant the matrix and inclusion phases of the composite are, the stronger the long-term memory effects are, especially when the inclusions are more compliant than the matrix. Similarly, the duration of the transient regime is significantly extended for sufficiently elongated, or flattened particle shapes, but only under certain modes of deformation. Finally, consistent with earlier work, significant Bauschinger effects are observed for cyclic loading conditions.