The self-consistent scheme is a common homogenization method that was developed to connect local deformation mechanisms to the overall behavior of heterogeneous disordered materials. In the past decades, many efforts have been made to obtain extensions of the self-consistent approximation to the non-linear case. This work focuses on the specific case of heterogeneous materials with an elastic-viscoplastic behavior. For such materials, the overall behavior is strongly dependent on the space-time couplings originating from the differential form of the local constitutive law. Different approaches have thus been developed to describe the impact of such complex couplings on the overall behavior.

In the present work, an internal variable self-consistent model for heterogeneous materials with an elastic-viscoplastic behavior is proposed. In order to obtain the stress and strain concentration relations, the first step consists of linearizing the viscoplastic flow rule using an affine procedure. The introduction of the homogeneous reference media with either a purely elastic or a purely viscoplastic behavior allows for writing the heterogeneous problem in the form of an integral equation. The purely thermoelastic and purely viscoplastic heterogeneous problems are then solved independently. Such solutions provide some strain and stress fields verifying compatibility and equilibrium conditions. Using the specific properties of the Green operators associated with the homogeneous reference media toward these fields, the solutions of the purely thermoelastic and purely viscoplastic heterogeneous problems are combined to obtain the final self-consistent approximation of the integral equation.

Some applications concerning polycrystalline materials are finally presented. To demonstrate the relevance of the proposed affine formulation, it is compared to the secant formulation of Paquin et al. (1999) and to the FFT spectral method, which provides reference results. When compared to the reference solutions, a good description of the overall response of heterogeneous materials is obtained with the proposed affine formulation even when the viscoplastic flow rule is highly non-linear. Also, the examination of the local stress and strain fields shows that, in comparison with the secant formulation, the interactions between the different grains are much better described with the affine formulation. Thanks to this approach, which is entirely formulated in the real-time space, the present model can be used for studying the response of heterogeneous materials submitted to complex thermo-mechanical loading paths with a good numerical efficiency.