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Mean-field modelling of dual-phase steel under non-monotonic loading conditions

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ABSTRACT

The present work addresses multi-scale modelling of the mechanical response of dual-phase (DP) steels, which can be viewed as composite materials made of hard martensitic grains embedded in a softer ferritic matrix. The considered micromechanical models aim at predicting the influence of the microstructure on the composites overall properties. The phase partitioning of the strain and stress fields is also assessed, since several microscopic processes are governed by local values of these fields (e.g.: damage initiation and propagation, phase transformations...).

To that purpose, mean-field approaches are likely to provide useful predictions. The overall behavior is computed based on the average response within individual phases. This helps identifying optimal microstructures while reducing computational costs as compared to full-field calculations. Most of these schemes rely on Eshelby's solution of the equivalent inclusion problem in a linear elastic, composite material subjected to small strains. Extensions to non-linear materials is performed by secant, tangent or variational linearization [1] of the actual material behavior, defining a so-called linear comparison composite (LCC) on which various homogenization schemes (Mori-Tanaka, self-consistent, double-inclusion...) can be applied. Incremental schemes [2-3], which relate stresses and strains rates using a different LCC at each load step, are suited for non-monotonic loading paths.

Here, we compare the ability of several recent mean-field models for predicting the average stress in the reinforcing phase during the deformation of the composite. Two volume fraction of particles (5% and 15%) and two loading cases (uniaxial or plane strain tension-compression cycles) are considered. The modelling assumes elasto-plastic matrix and linear elastic inclusions. Firstly, the first-order method relying on classical tangent operator is adapted according to a heuristic approach in order to reproduce the behavior of DP-steel [3]. Secondly, an new incremental second-order approach is tested. Finally, a mean-field approach based on the resolution of the isolated inclusion problem with ABAQUS is presented (Figure 1). In any case, the Mori-Tanaka method is used for the homogenization of the LCC. Results are compared with reference solutions provided by FE computations (Figure 2) on a statistically representative volume element of the DP-steel, with special emphasis on per-phase averages.

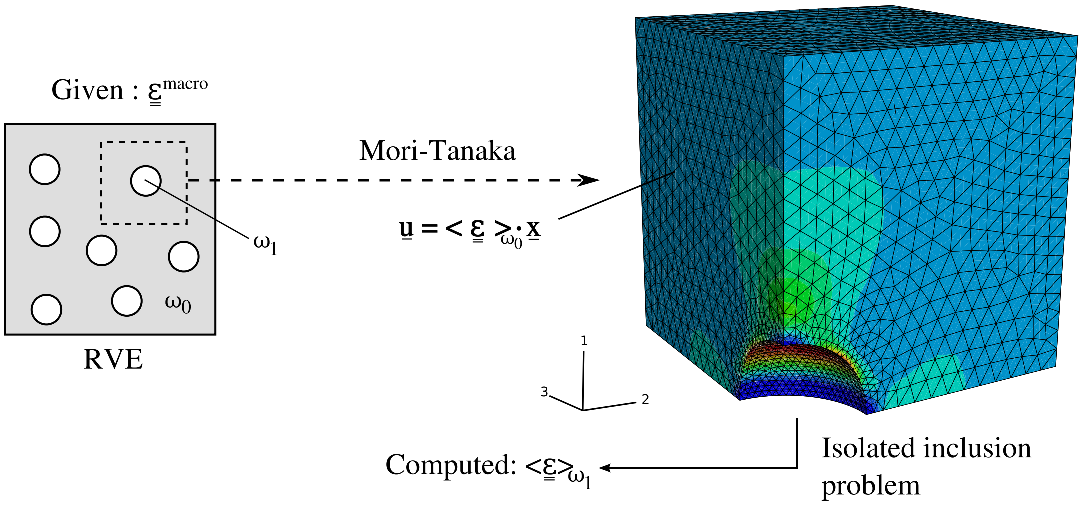

Figure 1: Numerical resolution of the isolated inclusion problem applying the Mori-Tanaka homogenization scheme.

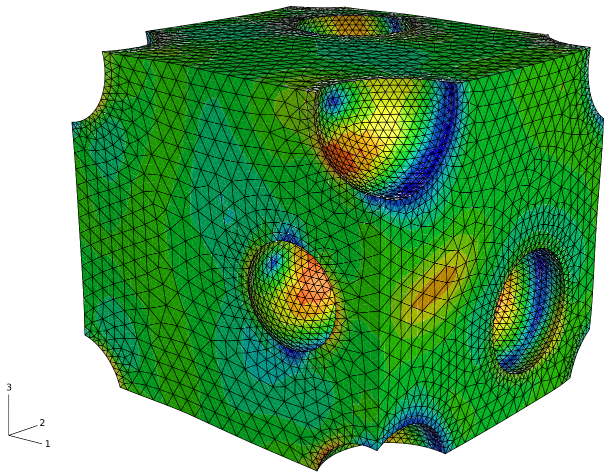

Figure 2: FE prediction of the von Mises stress in the matrix after 5% tension for a random ordering of 5 particles with 15% volume fraction.

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