Homogenization of particulate composites: inclusion packing effects

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Most of the analytical homogenization methods for particulate composites rely on the volume fraction of inclusions and their shape. Molinari and El Mouden [1] proposed a model taking into account the spatial distribution of inclusions, through the interactions between ellipsoidal elastic inclusions, in an elastic matrix. Kowalczyk-Gajewska et al. [2] extended the Cluster Model to elastic-viscoplastic composites, and showed that the spatial distribution of inclusions has a significant effect on the overall response of the material, especially at high volume fractions.

The present work aims at investigating how the spatial distribution of inclusions in a particulate composite affects the overall response of the material. For simple microstructures, such as periodic arrays of inclusions, the effective properties determined using analytical methods, such as Mori-Tanaka or the Cluster Model are compared to numerical results obtained using Finite Element simulations. By modeling different simple microstructures, the benefits and limits of the Cluster Model are highlighted, in comparison to Mori-Tanaka scheme. The response is anisotropic, depending on the position of the inclusions, in agreement with Finite Element results.

The range of validity of the Cluster Model is also discussed by increasing the volume fraction of inclusions. It is shown that the predictions of the Cluster Model remain reliable for higher volume fractions of inclusions than those from the Mori-Tanaka model. However, the Finite Element results show that when strains can no longer be considered as uniform in the inclusions, the Cluster Model fails to predict accurately the overall response of the material. This is due to the fact that it relies on the Berveiller et al. result [3] for two inclusions interacting in an infinite medium, according to which the field fluctuations within the inclusions are neglected. This underlines the need for a model to account as well for the interactions effects and for the non-uniformity of strains in the inclusions.

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