Anisotropy of Elasto-Plastic Composite Materials Induced by Spatial Distribution of Inhomogeneites

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Heterogenous materials always have posed significant difficulties in regard to assessing their macroscopic properties. Decades of development of various procedures based on numerical homogenisation now allow for a high level of detail and flexibility in terms of replicating different microstructure morphology, but consume a lot of computing power and time. Thus, many attempts have been made to develop analytical models that could provide robust and computationally efficient tools for this purpose.

In this presentation, an analytical approach to finding the effective response of elastoplastic composites using the cluster model with a modified tangent linearisation scheme is discussed [1]. It is based on the idea of Molinari & El Mouden (1996) [2] to extend classical mean-field models by taking into account the interactions between inhomogeneities within the material volume. Elastoplastic regime is examined for two material scenarios: matrix reinforced with inclusions or weakened with voids. Two Bravais lattices of cubic symmetry (regular cubic and body-centred cubic) are considered. For each case, periodic unit cells are generated and subjected to external isochoric and hydrostatic strain conditions. The results show a significant impact of the spatial arrangement of inhomogeneities on the overall material anisotropy, which is not accounted for by classical micromechanical mean-field models. Applied modified tangent linearisation scheme allows for the initiation of plastic flow even under hydrostatic loading scenarios.

The results of the analytical model are verified by comparison with those of numerical homogenisation performed using the Finite Elements Method (FEM) with meshing requirements discussed. The results from the cluster model are qualitatively and quantitatively, consistent with FEM.

Additional procedure for a multi-criteria optimisation is proposed. It shows that the cluster model might be an effective tool for finding the optimal microstructure (i.e. the optimal spatial arrangement of inhomogeneities or their volume fraction) for a given application of the material, allowing for a broad filtering of possible scenarios on the initial stage of the design process.

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[2] Molinari A., El Mouden M. (1996). The problem of elastic inclusions at finite concentration. *Int. J. Solids Structures*, 33, 3131–3150. https://doi.org/10.1016/0020-7683(95)00275-8