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Numerical Quantification of Uncertain Homogenized Material Properties Resulting from Variations of Microstructure Morphology

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An uncertain material behavior impedes an accurate assessment of structural engineering problems because a deterministic prediction of mechanical quantities associated with the failure of the structure can hardly be given. Especially modern materials, whose favorable properties are the result of a pronounced microstructure, are subjected to uncertainties regarding the macroscopic material properties due to a high variation of the microstructure morphology. Here, we present a method to characterize the macroscopic material behavior of these microheterogenous materials using advanced high strength steels as an example. The basis principle of the method is the simulation of a large set of microstructures with changing morphologies. These simulations are carried out in terms of finite elements and consecutive homogenization of micromechanical quantities to obtain the resulting macroscopic properties of the material. Each microstructure is selected in a way that the statistical variation of the set of microstructures is as similar as possible to the variation of microstructure morphology in the real material. This specification is obtained by an expansion of the concept of statistically similar representative volume elements (SSRVEs) [1]. An SSRVE is the result of a minimization problem, which is formulated as a least-square functional in terms of differences between statistical measures of the real material's morphology and the one of the SSRVE. The microstructures for the computed set are chosen such that the distribution of the least-square functional evaluations will follow the one obtained from the real material's microstructure. To have a fully automatic simulation of the varying geometries the simulations are carried out with the use of an adapted finite cell method [2]. Additionally a Multi-Level Monte-Carlo approach is used to reduce the required computational effort.

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