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COMPARATIVE STUDY FOR THE EFFICIENT CONSTRUCTION OF STATISTICALLY SIMILAR RVES

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A major aim of research and development in engineering applications is the improvement of application properties and the reduction of material consumption. In the field of steel applications, e. g. in the automotive industry, the use of advanced high strength steels (AHSSs), e. g. Dual-Phase steels (DP steels) offer such progress compared to the application of conventional high strength steels. The improved properties of AHSSs include higher strength and better formability, which enable lighter constructions. The advanced properties originate from the composition of the microstructure of the material: hard martensitic inclusions embedded in a soft ferritic matrix phase. The individual mechanical properties of each phase and their interaction during deformation result in the improvements in terms of overall properties. The incorporation of these heterogeneities is desirable for a realistic simulation and can be achieved by direct scale-bridging approaches such as the FE^2 method, cf. [1]. There, in each macroscopic finite element integration point, an underlying microscopic boundary value problem is solved, governed by a representative volume element (RVE), which is typically defined as a suitable portion of the real material microstructure.

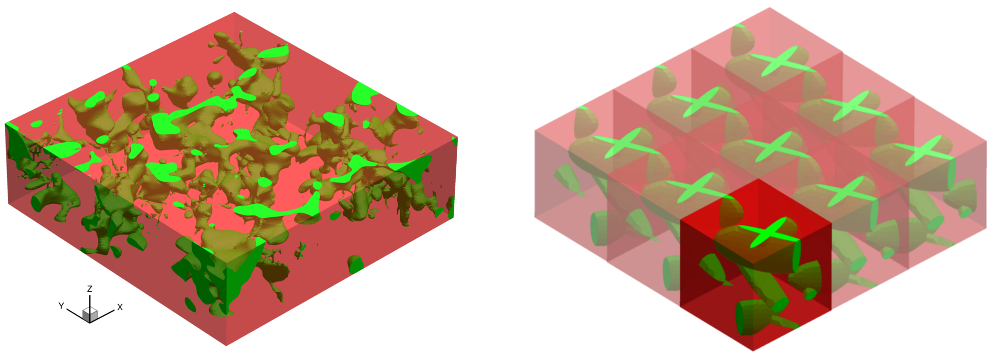

Figure 1: Real microstructure (left), obtained from 3D-EBSD measurements performed in the group of Prof. D. Raabe from Max-Planck Institute of Iron Research in Düsseldorf, and artificial microstructure (right) composed of periodically arranged SSRVEs.

Due to the complex morphology of such microstructures, a discretization involves a high number of finite elements, which results in high computing time. In the present work this issue is circumvented by replacing the RVE containing the original real (complex) microstructure by a less complex statistically similar RVE (SSRVE), which resembles the microstructure in terms of statistical measures characterizing the morphology. The idea is illustrated in Figure 1. Here, the real microstructure of a DP steel is replaced by an artificial one, composed of periodically arranged SSRVEs. The construction of the SSRVEs is realized in an optimization process. A least-square functional taking into account the difference of statistical measures calculated for the real microstructure and the SSRVE, with a given parameterization of the morphology, is minimized and results in a representation which is statistically similar to the original one, cf. [2].The statistical measures used in this approach play a crucial role. They should represent the real microstructure sufficiently while also resulting in reasonable computing time for the optimization process. As stated in [4] that one statistical measure alone cannot capture enough features for a sufficient representation, hybrid approaches including multiple statistical measures are favorable. Furthermore, higher order measures such as two-point probability and lineal-path function capture connectivity and long-range properties and result in better representations compared with the application of only scalar-valued parameters, cf. [3]. However, basic measures such as the phase fraction account for essential information. In this work we use the lineal-path function, spectral density, which is strongly correlated to the two-point probability, and phase fraction as statistical measures and analyze the applicability of Minkowski measures, cf. [5], as suitable descriptors. SSRVEs are constructed based on the presented approach and analyzed regarding their mechanical response in comparison with the real microstructure.

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