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Multifidelity ductile failure model by cokriging between simulations on unit cells and random microstructures

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The predictions of analytic models of ductile failure are frequently compared with finite element simulations of elastoplastic cells embedding voids. Although unit cells with a single void are mostly used, microstructures with a random population of voids (as in [1]) can better represent interactions between voids. This work aims to build a model for ductile failure from simulations on random microstructures. As such simulations imply a high computational cost, a multifidelity approach with the Multiple Output Gaussian Processes (MOGP) methodology [2] is used to combine numerous simulations on simpler unit cells and a reduced number of expensive computations on random microstructures into a more precise model. More precisely, cubic cells consisting of an elastoplastic matrix with a single void or a random population of voids are simulated by finite elements up to failure. A proportional mechanical loading characterized by the average Cauchy stress tensor is applied; it is defined by its eigenvalues and the 3D orientation of the loading with respect to the cell. Due to the intrinsic anisotropy of the simulation cell the failure strain depends on the loading orientation. However only the orientation yielding the earliest failure (at given principal stresses) is physically relevant. Moreover, only the results in this optimal direction are correlated between the unit cell and the random microstructure. A two-step approach is therefore used. From a set of initial computations, two independent Gaussian process regressions in five dimensions are performed, for the unit cell and the random microstructures, in order to estimate the optimal failure strain. The MOGP method is then carried out between the two estimated optimal failure strain models. This methodology allows to harness the correlation between results on unit and random cells, allowing to build a surrogate model valid for random microstructures at a lower computational cost, and find optimal loading conditions for subsequent simulations.

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