Viscoplasticity of voided cubic crystals under hydrostatic loadings

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In this work a model based on an infinite-rank laminates approach (M. I. Idiart, 2008) is used in order to obtain an estimate of the macroscopic stress potential of a viscoplastic porous single crystal under hydrostatic loading.

The porous crystal is seen as a continuous crystalline matrix phase containing a statistically uniform dispersion of voids whose characteristic size is much smaller than the crystal size. This kind of microstructure characterises irradiated austenitic stainless steels, where voided pores appear inside grains of the polycrystalline structure (F. A. Garner, 2012).

In the infinite-rank laminates model the effective stress potential is the solution of a differential equation of Hamilton-Jacobi type. In the particular case of a hydrostatic effective stress and where the viscoplastic behavior of the crystalline matrix is of a power law type, this equation leads to an ordinary differential equation for the hydrostatic flow stress. The hydrostatic point of the effective gauge surface is obtained up to a coefficient depending on the material parameters, which is determined numerically. Analogous results for isotropic matrix were obtained by J. C. Michel and P. Suquet (1992) for viscoplastic matrix and by A. L. Gurson (1977) for rigid plastic matrix, by mean of analytical developments carried out on the hollow sphere. Similar results were proposed by X. Han et al. (2013) and by J. Paux et al. (2015) for plastic porous single crystals.

Three kinds of crystalline matrix with cubic symmetry are considered: face-centered cubic matrix, body-centered cubic matrix and ionic matrix. In each case the predictions of the model are compared with the results of full field numerical simulations based on the Fast Fourier Transform method (H. Moulinec, P. Suquet, 1994). A good match is obtained between FFT results and the model predictions for different porosities and different creep exponent. This comparison allows us to propose an ad-hoc expression for the hydrostatic flow stress.

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