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Porous plasticity: predictive second moment homogenization models coupled with Gurson's single cavity stress-strain solution

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Abstract

An original and rather simple micromechanical approach is proposed for the case of a rigid plastic von Mises matrix containing multiple spherical cavities and subjected to linear velocities on the boundary. The approach couples mean-field homogenization with Gurson's single cavity stress-strain solution. The actual porous microstructure is modeled alternatively as spherical rigid plastic inclusions in a homogenized Gurson matrix phase and the volume fractions are determined from a maximum packing argument. The alternative microstructures are homogenized with the Generalized self-consistent (GSC) and Mori-Tanaka (MT) models which are formulated with the secant method and second statistical moments of per phase strain fields. Numerical predictions of effective yield envelopes in the plane of hydrostatic and von Mises stresses are verified against full-field finite element (FE) and analytical results for a large range of porosities. No fitting or empirical parameters are used in GSC or MT. It is found that the agreement between GSC and FE predictions is excellent, except when both the porosity and the stress triaxiality are small. The evolution of porosity as a function of the mean accumulated plastic strain in the solid matrix phase of the original microstructure is computed and illustrated for two effective stress triaxiality ratios.

Keywords: Porous plasticity, micromechanics, homogenization, Gurson's solution.

1. Introduction

In his seminal work, Gurson (1977) solved the problem of a single spherical cavity in a rigid von Mises plastic matrix subjected to linear velocities at the boundary corresponding to a macroscopic rate of deformation D_{ij}. Using limit analysis, he found an estimate of the effective (macro) yield condition of the homogenized material which depends on both von Mises equivalent stress and hydrostatic stress:

$$\left(\frac{\Sigma_{eq}}{\sigma_0}\right)^2 + 2f\cosh\left(\frac{1}{2}\frac{\Sigma_{ll}}{\sigma_0}\right) - 1 - f^2 = 0, \tag{1}$$

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