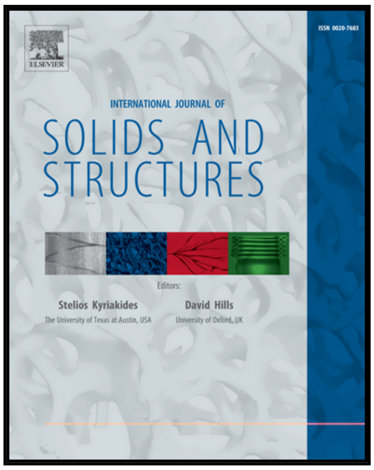
Accepted Manuscript



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PII: S0020-7683(17)30394-3
DOI: 10.1016/j.ijsolstr.2017.08.030
Reference: SAS 9709

To appear in: *International Journal of Solids and Structures*

Received date: 9 March 2017
Revised date: 24 August 2017
Accepted date: 28 August 2017

Please cite this article as: J. Paux, R. Brenner, D. Kondo, Plastic yield criterion and hardening of porous single crystals, *International Journal of Solids and Structures* (2017), doi: 10.1016/j.ijsolstr.2017.08.030

Plastic yield criterion and hardening of porous single crystals

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Abstract

This article presents an assessment of the yield criterion for porous plastic single crystal, proposed by Paux et al. (2015), for face-centred cubic and hexagonal close-packed crystalline structures. Comparisons with reference FFT full-field computations on single voided cubic unit cells, presenting different crystal orientations, show an overall agreement for the different plastic anisotropies considered at low and high triaxiality. An extension of the criterion to hardenable crystals, which takes into account the spatial heterogeneity of the approximate plastic strain field, is further proposed and compared with FE results from the literature for body-centred cubic crystals.

Keywords: plasticity, single crystal, porosity, micromechanics

1. Introduction

The porosity evolution during the plastic deformation of metallic materials is known to play a dominating role in the fracture process. Voids are often initially present in the material due to the manufacturing process (infinitesimal porosity) or they can be created during the deformation due to the decohesion between precipitates and matrix phase. In any case, the description of void growth process requires to develop constitutive laws for the plastic response of porous crystalline materials with a special attention to the plastic anisotropy.

Although the importance of the crystalline anisotropy to describe the local stress field in the vicinity of intragranular voids has been clearly evidenced (Crépin et al., 1996; Gan et al., 2006; Schacht et al., 2003; Yerra et al., 2010; Srivastava and Needleman, 2013), relatively few works on the constitutive response of 3D plastic single crystals containing voids have been undertaken until recently. Based on the variational homogenization method of de Botton and Ponte Castañeda (1995) and guided by limit-analysis results, Han et al. (2013) have first proposed a yield function for 3D porous FCC single crystals containing spherical voids. Afterwards, we have proposed a model based on limit analysis which makes use of a regularized form of the Schmid law. It shares similarities with Han's model despite being derived with a different approach (Paux et al., 2015). Besides, by using on a "modified" variational method proposed by Danas and Aravas (2012), Mbiakop et al. (2015a) have developed a model for viscoplastic single crystals with ellipsoidal voids. Interestingly, the authors have also shown that these three models deliver very close estimates for rate-independent porous plasticity in the case of low plastic anisotropy (namely, face-centered cubic crystals) and spherical voids. Concerning the microstructural

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