20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

On the coupled effects of strain hardening and void shape upon the ductile behaviour of metals subjected to cyclic loadings

Jean-Baptiste Leblond[1]

[1] Sorbonne Universite, France. JBLeblond57@gmail.com

Paper ID: 77
Symposium S8: Fracture, and damage of materials

Abstract

It is a well-established experimental fact that the ductility (strain to fracture) of metals is considerably lower under cyclic loadings than under monotone ones. The phenomenon is currently ascribed to an effect of ratcheting of the porosity (increase, with the number of cycles, of the maximum porosity reached during one cycle) under such conditions. This effect has been the topic of a number of theoretical works devoted to its modelling through analysis of micro-mechanisms and homogenization, and numerical works devoted to micromechanical simulations of the cyclic ductile behaviour of porous Representative Volume Elements (RVEs). It has notably been shown by Devaux et al. on theoretical arguments, as early as 1995, that the ratcheting of the porosity can only arise from two (possibly coupled) effects, namely those of strain hardening and elasticity. The present work considers only the effect of strain hardening. An interesting theoretical avenue was opened by Morin et al. (2017), using the framework of sequential limit-analysis (Yang, 1993; Leu, 2007; Leblond et al., 2018). This approach considered a spherical RVE containing a spherical cavity, in which a heterogeneous distribution of (isotropic, kinematic or mixed) hardening was accounted for through discretization into a finite number of spherical layers, in each of which hardening was considered as homogeneous. Morin et al. (2017)'s work was very recently extended by Roubaud et al. (2024) so as to incorporate void shape effects, by considering an ellipsoidal RVE containing an ellipsoidal void. The idea of discretization of the RVE into a finite number of layers was retained, except for the shape of these layers which became ellipsoidal instead of spherical. Heavy use was made of previous analyses (Madou and Leblond, 2012, 2013) of the behaviour of porous, ideally-plastic materials containing ellipsoidal voids. The aim of the present work is to assess the predictive power of Roubaud et al. (2024)'s model, through comparison of its predictions with the results of some new micromechanical simulations of the cyclic behaviour of porous ductile solids containing ellipsoidal cavities, and exhibiting various types of hardening. We especially concentrate on typical cases where the influences of hardening and void shape are strongly coupled. The first case is that of initially spherical cavities and relatively low triaxialities of the external load. The growth of the porosity is then limited. However significant ratcheting effects, depending on the type and importance of hardening, are predicted by the model for the void's shape and orientation. The second case is that of initially non-spherical voids but high triaxialities. The growth of the porosity is then important, and the predicted ratcheting effect is highly dependent upon the initial shape (elongated or flat) of the void, and the type and importance of hardening. In both cases the potential influence of ratcheting effects upon future coalescence of voids is important. The numerical framework developed by Tekoglu and Kochan (2022), for the finite-element-based study of the behaviour of porous plastic RVEs subjected to arbitrary loadings, is finally employed to assess the correctness of model predictions, with generally good results.

Keywords:

Ductile materials Cyclic loadings Strain hardening Void shape Theoretical modelling Micromechanical simulations