



**HAL**  
open science

# Finite Element Modeling of Void Nucleation, Growth and Coalescence for Large Plastic Strain and Complex Loading Paths

Pierre-Olivier Bouchard, Emile Roux, Marc Bernacki

## ► To cite this version:

Pierre-Olivier Bouchard, Emile Roux, Marc Bernacki. Finite Element Modeling of Void Nucleation, Growth and Coalescence for Large Plastic Strain and Complex Loading Paths. The Third International Conference on Computational Modeling of Fracture and Failure of Materials and Structures, Jun 2013, Prague, Czech Republic. pp.94. <hal-00845437>

**HAL Id: hal-00845437**

**<https://minesparis-psl.hal.science/hal-00845437v1>**

Submitted on 17 Jul 2013

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

## Finite element modeling of void nucleation, growth and coalescence for large plastic strain and complex loading paths

P.-O. Bouchard<sup>1\*</sup>, E. Roux<sup>1</sup>, M. Bernacki<sup>1</sup>

<sup>1</sup> Centre de mise en forme des matériaux (CEMEF), Mines Paristech, UMR CNRS 7635, BP 207, 06904 Sophia Antipolis Cedex, France, pierre-olivier.bouchard@mines-paristech.fr

Ductile damage prediction is still an important issue in the mechanical industry. Ductile failure criteria as well as coupled damage models were enhanced in the last decade by accounting for the influence of stress triaxiality ratio and Lode angle. For the Gurson-Tvergaard-Needleman (GTN) model, these improvements were essentially made for the growth and coalescence stages based on unit-cell models in which the behavior of a single ellipsoidal void is studied under various loading conditions [1]. In the present work, the stage of nucleation is also addressed in addition to void growth and coalescence for large plastic strain and different particle/void morphologies.

- Microstructure representation

Heterogeneous microstructures with particles and voids in a metallic matrix are considered. This heterogeneous microstructure is meshed using level-set functions - to define interfaces between matrix, inclusions and voids - and anisotropic mesh adaptation. This anisotropic mesh adaptation is particularly well suited for macroscopic [2] and microscopic [3] ductile damage problems.

- Mechanical failure criteria

Nucleation starts either by particle failure or by debonding at particle-matrix interfaces. For debonding nucleation (respectively particle failure), the failure criterion is based on interfacial normal and tangential stresses (respectively maximum principal stress in particles). The void growth stage is based on plastic strain around void during the deformation stage. Finally coalescence is activated when a critical plastic strain value is reached between two growing voids. It has to be noticed that this coalescence criterion can be easily transformed in a criterion based on the distance between neighbouring voids.

- Numerical failure techniques

Once the failure criterion is reached, two different numerical techniques can be used to model failure:

- Germ-based method: a void germ, represented by a new level-set function, is created at the location for which the failure criterion was reached. The interface between this void and the matrix (or particle) is well described thanks to the anisotropic mesh adaptation.

- Failure plane method: an instantaneous failure plane, modelled by a level-set function, is created once the critical failure criterion is reached. For good accuracy, particular attention has to be paid to the mesh refinement in the area in which this failure plane is created.

The two methods are compared and their advantages and drawbacks are presented in terms of numerical accuracy and physical representation of ductile failure mechanisms.

- Applications

Several 2D and 3D applications are presented. The influence of failure parameters and loading conditions are studied for simple microstructures and for real microstructures coming from scanning electron microscopy (SEM) images.

### References

- [1] D. Fabrègue and T. Pardoen, A constitutive model for elastoplastic solids containing primary and secondary voids, *J. Mech. Phys. Solids* 56 (2008) 719-741.
- [2] R. El Khaoulani and P.-O. Bouchard, An anisotropic mesh adaptation strategy for damage and failure in ductile materials, *Finite Elements in Analysis and Design* 59 (2012) 1-10.
- [3] E. Roux, M. Bernacki and P.-O. Bouchard, A level-set and anisotropic adaptive remeshing strategy for the modeling of void growth under large plastic strain, *Computational Materials Science* 68 (2013) 32-46.